Spectrum Management for the Cisco Cable Modem Termination System

This chapter describes the spectrum management features supported by the Cisco Cable Modem Termination System (CMTS) universal broadband routers. It includes the following major sections:

Note This chapter provides configuration information but not a complete command reference. For complete information on the commands used in this chapter, see the *"Cisco Cable Modem Termination System Commands"* chapter in the *Cisco Broadband Cable CommandReference Guide*, available on Cisco.com and the Customer Documentation CD-ROM.

Note Advanced spectrum management features on the Cisco uBR-MC16S cable interface line card will be enabled with future Cisco IOS releases. Future advanced spectrum management support will include CNR-based frequency hopping and configurable hopping priorities."

Feature Overview

Spectrum management is a software and hardware feature provided in the Cisco Cable Modem Termination System (CMTS) so that the CMTS may sense both downstream and upstream plant impairments, report them to a management entity, and automatically mitigate them where possible. The CMTS directly senses upstream transmission errors. It may also indirectly monitor the condition of the plant by keeping a record of modem state changes. The spectrum management feature performs these functions without reducing throughput or latency and without creating additional packet overhead on the radio frequency (RF) plant.

The purpose of spectrum management is to prevent long-term service interruptions caused by upstream noise events in the cable plant. It is also used for fault management and troubleshooting the cable network. When cable modems are detected to go online and offline by flap detectors, the cable operators can look at the flap list and spectrum tables to determine the possible causes.

Due to the nature of cable television (CATV) technology, upstream noise management is a significant issue. Frequency bands must have a sufficient carrier-to-noise ratio (CNR) and carrier-to-ingress power ratio to support the transmission of quadrature phase-shift keying (QPSK) and quadrature amplitude modulation (QAM) data. The Data-over-Cable Service Interface Specifications (DOCSIS) set the minimum value for both of these ratios to 25 dB in the 5-MHz to 42-MHz frequency range. If the CNR drops below 25 dB on a particular channel due to noise, the cable modem on that channel degrades and can drop off the hybrid fiber-coaxial (HFC) network.

This overview contains the following subsections:

Subsection	Description
Upstream Signal Channel Overview, page 3-3	Describes how signals are sent and how changes occur in upstream channels.
Upstream Segments and Combiner Groups, page 3-4	Describes sparse and dense segments and combiner groups.
Frequency Management Policy, page 3-5	Describes the types of noise impairments and how to counteract ingress noise with spectrum groups and frequency hopping.
Phases of Spectrum Management, page 3-6	Describes the three phases of spectrum management and the Cisco IOS releases in which support started.
Guided and Scheduled Spectrum Management, page 3-7	Describes the following Guided and Scheduled spectrum management features: traffic shaping, frequency hopping capabilities, dynamic upstream modulation (SNR-based), and input power levels.
Advanced Hardware-Based Spectrum Management, page 3-14	Describes spectrum management features that are supported by the Cisco uBR-MC16S and Cisco uBR-LCP2-MC16S cable interface line cards: • Intelligent spectrum management capabilities that include a spectrum analyzer for more intelligent and faster frequency hopping • Advanced spectrum management features that include CNR-based, proactive frequency hopping and a more robust dynamic upstream modulation

Upstream Signal Channel Overview

The upstream channel is characterized by many cable modems transmitting to the CMTS. These signals operate in a burst mode of transmission. Time in the upstream channel is slotted. The CMTS provides time slots and controls the usage for each upstream interval. The CMTS periodically broadcasts Upstream Channel Descriptor (UCD) messages to all cable modems. The UCD message contains the upstream frequency and transmission parameters associated with an upstream channel. These messages define upstream channel characteristics including the upstream frequencies, symbol rates and modulation schemes, forward error correction (FEC) parameters, and other physical layer values.

Cisco supports all DOCSIS error-correction encoding and modulation types and formats. Upstream signals are demodulated using QPSK or QAM. QPSK carries information in the phase of the signal carrier, whereas QAM uses both phase and amplitude to carry information.

Sending data reliably in the upstream direction is an issue. Because upstream spectrum varies greatly between cable plants, select upstream parameters based on your cable plant's return paths. Select or customize upstream profiles for maximum trade-off between bandwidth efficiency and upstream channel robustness. For example, QAM-16 requires approximately 7 dB higher CNR to achieve the same bit error rate as QPSK, but it transfers information at twice the rate of QPSK.

Note The above specifications are based on predetermined sets of frequencies that may or may not have an adequate CNR at any given time.

Upstream frequencies can be assigned as follows:

- Fixed—Configuring a spectrum group disables the fixed upstream frequency setting.
- Single subband—The CMTS administrator can define a center frequency and symbol rate such that the boundaries of the upstream carrier stay within the subband. The frequency and symbol rate can change within the boundary in response to noisy line conditions, based on the defined upstream parameters.
- Multiple subbands—The data carrier can remain in a particular subband for a duration of time and then hop to another subband based on the defined upstream parameters.

Tip Measurement of noise power levels with a spectrum analyzer should be part of the procedure in initially selecting and setting up frequency allocations. Cisco recommends having fixed frequency settings during early deployment, at least until amplifier cascade adjustments or plant repair have become infrequent enough that they no longer significantly affect the nodes connected to the upstream port.

Upstream Frequency Changes

As stated in the DOCSIS radio frequency interface (RFI) specification, RF channel migration or upstream frequency change occurs when a change in the UCD message is broadcast to all cable interfaces.

The speed of channel migration via the UCD message is typically less than 20 milliseconds (ms). During this time, upstream transmission is interrupted until the cable interface transmitter adjusts to its new frequency. Data is stored in the cable interface's buffers during this time and is sent when the frequency hop is complete.

Station maintenance intervals are used to perform per-modem keepalive polling. The CMTS polls each cable modem at least once every 30 seconds, with the default being once every 25 seconds. When ingress noise causes loss of keepalive messages from a configurable percentage of all cable interfaces, resulting in missed polls, a new frequency is selected from the allocation table and a UCD update is performed. The migration time is 2 msec for any upstream UCD update. After the UCD is updated, the hop occurs. The system must wait until a hop-threshold time interval has elapsed before it can change the UCD a second time.

Upstream Segments and Combiner Groups

The Cisco routers divide a cable plant into downstream channels. Downstream channels contain upstream segments. Each upstream segment typically serves more than one fiber node. Upstream segments can be defined as one of the following:

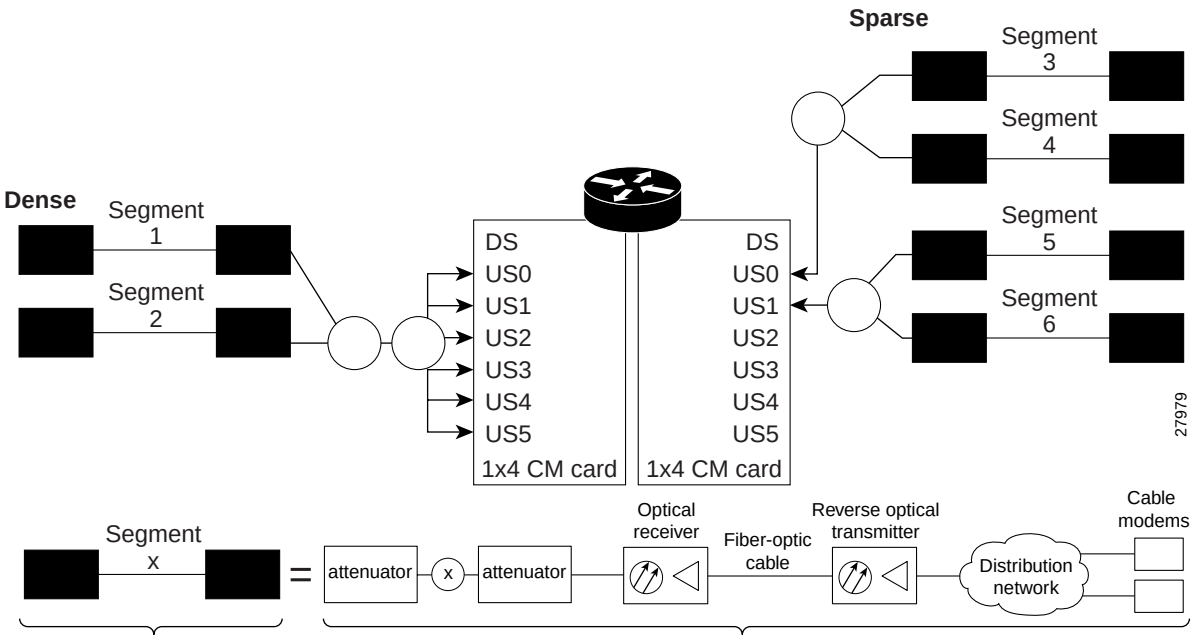
- Sparse segment—Containing one upstream channel per upstream segment.
- Dense segment—Containing multiple upstream channels per upstream segment; frequencies must be different.

Note A cable interface line card can support sparse or dense segments, or both.

Defining sparse segments allows the cable operator to share upstream bandwidth among fiber nodes with fewer subscribers. Defining dense segments allows the cable operator to provide larger upstream bandwidth to fiber nodes with many subscribers.

Figure 3-1 illustrates sparse versus dense segments.

Figure 3-1 Sparse Versus Dense Segment Illustrations



As shown in Figure 3-1, the downstream segment can contain multiple upstream segments. Two fiber nodes can be in one downstream segment but in different upstream segments.

The return path of several fiber nodes can be combined at a single point to form a single RF frequency domain called a combiner group. The CMTS software allows a frequency hop table called a spectrum group to be associated with a combiner group.

Note A combiner group refers to an RF topology point. A spectrum group refers to the frequency hop table associated with a combiner group.

Frequency Management Policy

Spectrum management applies a common frequency-management policy to a set of upstream ports to ensure that data is delivered reliably over the cable plant. Cable plant operators must make noise measurements and determine the cable plant's spectrum management policy. Different modulation schemes, upstream frequency techniques, and symbol rates are used based on the cable plant characteristics and the cable interface line card in the chassis.

Noise Impairments

Upstream noise impairments such as signal degradation on cable networks can negatively affect service to subscribers. Two-way digital data signals are more susceptible than one-way signals to stresses in the condition of the HFC network. Degradation in video signal quality might not be noticeable in one-way cable TV service, but when two-way digital signals share the network with video signals, digital signals can be hampered by:

- Impulse and electrical signal ingress—Noise can enter the network from electrical sources within a residence or from high-voltage lines that run near CATV cabling. Two types of ingress noise include broadband and narrowband. Broadband noise is generally of lower frequency (below 10 MHz) and results in harmonic rolloff. Narrowband noise is a more significant interference source. Cable equipment and infrastructure often pick up noise from amateur radio transmissions, citizen band radios, or high-power shortwave broadcast signals. Implement a signal leakage maintenance program to locate and repair areas of signal ingress.
- Amplifier noise—Amplifiers add noise to the HFC network that typically goes unnoticed in video signals, but degrades digital data signals if amplifiers are improperly configured. The larger the network, the higher the probability of amplifier noise affecting signals.
- Noise funneling—The upstream data path to the headend is susceptible to interference from the entire network. All upstream noise ultimately ends up at the headend because the cumulative nature of noise becomes concentrated at the headend. As a network serviced by a single RF receiver increases in size, the probability of noise funneling also increases.
- Variable transmit levels—Temperature affects signal loss over coaxial cable. This can cause variations of 6 to 10 dB per year.
- Clipping—The lasers in fiber-optic transmitters can stop transmitting light when input levels are excessive. Excessive input levels introduce bit errors in both the upstream and downstream transmissions. If a laser is overdriven as briefly as a fraction of a second, clipping can occur.

To adjust your return amplifiers and lasers, follow rigorous plant maintenance procedures documented in the *NTSC Supplement on Upstream Transport Issues* or appropriate cable plant standard. Also refer to the hardware installation guide that ships with your CMTS.

Spectrum Groups and Frequency Hopping

Cisco recommends that CMTS administrators configure upstream frequency hopping to counteract long-term, narrowband noise. Cisco routers support a combination of guided frequency hopping and time-scheduled frequency hopping.

The frequency hop to proactively avoid noise ingress is sometimes called frequency agility. Frequency agility is configured and activated using spectrum groups. Spectrum management supports the creation of as many as 32 cable spectrum groups, allowing multiple upstream ports in a single spectrum group, and specifications of configured channel-widths for upstream segments. Each spectrum group defines the table of frequencies to be used in a specific frequency plan. Upstream frequencies can be fixed, single subband, or multiple subbands.

The cable interface does not operate until you either create and configure a spectrum group or set a fixed upstream frequency. Configuring a spectrum group disables the fixed upstream frequency setting. From the interface configuration prompt, an interface is assigned membership in a spectrum group. From the interface point of view, the spectrum group also represents the set of upstreams connected to the same group of fiber nodes. The spectrum manager software in Cisco routers determines if upstream frequencies need to be managed together.

The upstream ports use a spectrum group to implement a frequency hopping technique. The types of frequency hopping techniques are guided, time-scheduled, and a combined guided and time-scheduled. See the "Frequency Hopping Capabilities" section on page 3-10 for more information on the types of frequency hopping techniques.

Note When each upstream port has its own RF domain, the group is called a nonshared spectrum group. When multiple upstream ports share the same RF domain, the group is called a shared spectrum group.

Guidelines for Spectrum Management

In general, when defining your spectrum, use the following guidelines:

- Avoid frequencies with known ingress problems, such as amateur radio bands or short-wave bands.
- Avoid hostile spectrum below 20 MHz.
- Allow extra bands for frequency hopping.
- Place upstream ports in the same combiner group in a shared spectrum group.
- Use the receive power level setting to perform slight equalization adjustments.
- When multiple upstream ports are combined to provide increased bandwidth, care should be taken to prevent overlapping frequency bands.

Phases of Spectrum Management

The CMTS provides at least three phases or periods of spectrum management when different features or enhanced features have been added in different IOS releases:

- Guided and Scheduled spectrum management—Uses Cisco uBR-MC11C, Cisco uBR-MC12C, Cisco uBR-MC14C, Cisco uBR-MC16C, and Cisco uBR-MC28C cable interface line cards.
- Intelligent spectrum management using the Cisco MC16S cable interface line card—Based on the Cisco uBR-MC16C cable interface line card plus a spectrum management daughter card.
- Advanced spectrum management—Uses the Cisco uBR-MC16S cable interface line card and daughter card, an upgrade that provides additional features.

Note Unless otherwise indicated, all references to Cisco cable interface line cards apply to both the Cisco uBR7200 series versions and the Cisco uBR10012 versions.

Table 3-1 summarizes the spectrum management phases.

Table 3-1 Spectrum Management Phases

	Guided and Scheduled Spectrum Management	Intelligent Spectrum Management Using uBR-MC16S Card	Advanced Spectrum Management Using uBR-MC16S Card
Cisco IOS release supported	11.3(9)NA, 12.0(5)T1, 12.0(6)SC, 12.1(1), 12.1(1)T, 12.1(2)EC, 12.2(2)XF, 12.2(4)BC1b, and later. See Table 3-2 on page 3-8 for more detailed information.	12.1(2)EC and later, 12.2(8)BC2[1]	12.1(7)CX[2], 12.2(8)BC2[1]
Platforms supported	Cisco uBR7100 series Cisco uBR7223 Cisco uBR7246 Cisco uBR7246 VXR Cisco uBR10012 router	Cisco uBR7223 Cisco uBR7246 Cisco uBR7246 VXR Cisco uBR10012 router	Cisco uBR7223 Cisco uBR7246 Cisco uBR7246 VXR Cisco uBR10012 router
Cable interface line card used	Cisco uBR-MC11C Cisco uBR-MC12C Cisco uBR-MC14C Cisco uBR-MC16C Cisco uBR-MC16E Cisco uBR-MC28C Cisco uBR-MC28C-BNC	Cisco uBR-MC16S	Cisco uBR-MC16S
Description	Works with every cable interface line card except the original Cisco uBR-MC11-FPGA cable interface line card.	Based on the Cisco uBR-MC16C cable interface line card motherboard plus an additional piggyback, spectrum management daughter card. Delivers hardware-assisted, initial spectrum management enhancements.	An upgrade for the Cisco uBR-MC16S cable interface line card plus spectrum management daughter card. Provides CNR-based, proactive frequency hopping and spectrum management.

1. The Cisco uBR10012 universal broadband router using Cisco IOS Release 12.2(8)BC2 supports a subset of the Intelligent and Advanced Spectrum Management features. See the "Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support" section on page 3-19 for more details.
2. Cisco IOS Release 12.1(7)CX was an early deployment release that introduced the Advanced Spectrum Management features. This release is no longer available and has been superceded by Cisco IOS Release 12.2(8)BC2.

Guided and Scheduled Spectrum Management

Guided and Scheduled spectrum management constitutes a set of basic features that use the Cisco uBR-MCxxC, Cisco uBR-MC28C, and Cisco uBR-MC28C-BNC cable interface line cards. These features were introduced in a range of Cisco IOS releases, from Cisco IOS Release 11.3(9)NA, Cisco IOS Release 12.0(5)T1, Cisco IOS Release 12.0(6)SC, Cisco IOS Release 12.1(3a)EC1, Cisco IOS Release 12.2(1)XF, Cisco IOS Release 12.1(1)T, and Cisco IOS Release 12.1(2)EC1. These features are considered basic because they constitute the elementary, cornerstone features upon which the Intelligent and Advanced spectrum management features using the Cisco uBR-MC16S card are built.

See Table 3-2 on page 3-8 for a summary of the Guided and Scheduled spectrum management features and the Cisco IOS release in which it was introduced and subsequently supported.

Table 3-2 Summary of Guided and Scheduled Spectrum Management Features by Release

Feature	Cisco IOS Release Supported
Traffic Shaping, page 3-8 Upstream Traffic Shaping, page 3-9 Downstream Traffic Shaping, page 3-10	11.3(6)NA, 11.3(9)NA and later releases 11.3(6)NA, 12.0(5)T1, 12.1(2)EC1, and later releases
Guided Frequency Hopping, page 3-11[1]	12.0(5)T1 and later releases for Cisco uBR-MC1*x*C cable interface line cards 12.1(4)EC, 12.1(6), 12.1(6)T, 12.0(13)SC, and later releases for Cisco uBR-MC16E cable interface line cards
Time-Scheduled Frequency Hopping, page 3-12	12.0(5)T1 and later releases for Cisco uBR-MC1*x*C cable interface line cards 12.1(4)EC, 12.1(6), 12.1(6)T, 12.0(13)SC, and later releases for Cisco uBR-MC16E cable interface line cards
Dynamic Upstream Modulation (SNR-based), page 3-12	12.1(3a)EC1 and later releases for Cisco uBR-MC1*x*C and Cisco uBR-MC28C cable interface line cards 12.1(4)EC, 12.1(6), 12.1(6)T, 12.0(13)SC, and later releases for Cisco uBR-MC16E cable interface line cards
Input Power Levels, page 3-13	12.0(6)SC, 12.1(1), 12.1(1)T, 12.1(2)EC1, and later releases

1. Cisco IOS Release 12.0(5)T1 also provided initial CISCO-CABLE-SPECTRUM MIB with flap-list support.

Traffic Shaping

Traffic shaping basically uses queues to limit data surges that can congest a network. The data is buffered and then sent into the network in regulated amounts to ensure that the traffic fits within the expected traffic envelope for the particular connection.

Traffic shaping reduces the chance that information must be retransmitted to hosts on the cable plant. When cable modems (CMs) have rate limits established, the CMTS typically drops data packets to enforce the rate limit. Dropping packets from the requesting CM causes the host sending the information to retransmit its information, which wastes bandwidth on the network. If both hosts sending and requesting information are on the cable plant, the upstream bandwidth is wasted as well.

Traffic shaping allows the CMTS to perform upstream and downstream rate limiting on the DOCSIS upstream and downstream channels. Rate limiting is supported in DOCSIS-1.0-99. Rate limiting restricts the data rate to and from a CM; the MAC scheduler supports traffic-shaping capabilities for downstream and upstream traffic. Rate limiting ensures that no single CM consumes all of the channel bandwidth and allows a CMTS administrator to configure different maximum data rates for different subscribers. Subscribers requiring higher peak rates and willing to pay for higher rates can be configured with higher peak rate limits in their CM DOCSIS configuration file over regular subscribers, who pay less and get lower rate limits.

Each time a packet belonging to a flow is transmitted on an output channel, the token-bucket policer function checks the rate limit status of the flow, passing the following parameters:

- Token bucket peak rate in bits/msec.
- Token bucket depth (maximum transmit burst) in bits.
- Length of current packet to be sent in bits.
- Pointer to the flow's token bucket.
- Pointer to the flow's token bucket last update time stamp.
- Variable to return the msec buffering delay in case the packet needs to be shaped.
- Maximum buffering delay that the subsequent traffic shaper can handle in msecs.

Every flow has its own shaping buffer where rate-exceeded packets are typically held back in first-in/first-out (FIFO) order for later transmission.

Tip Token bucket policing with shaping is the new per-upstream default rate limiting setting at the CMTS. Shaping can be enabled or disabled for the token-bucket algorithm.

Upstream Traffic Shaping

Upstream traffic shaping allows the CMTS to perform rate limiting on a DOCSIS upstream channel. The upstream traffic shaping feature delays the scheduling of the upstream packet, which in turn, causes the packet to be buffered on the cable modem device, instead of being dropped. This allows the user TCP/IP stack to pace the application traffic appropriately and approach throughput commensurate with the subscriber's defined quality of service (QoS) levels. Upstream traffic shaping enables the CMTS to enforce the peak upstream rate for each CM without degrading overall TCP performance for the subscriber CMs.

When you do not enable the shaping option for upstream rate limiting, the CMTS upstream-rate-policing code drops bandwidth requests from cable modems that are found to have exceeded their configured-peak-upstream rate (using different local drop policies). The effect of bandwidth requests (eventually upstream packets) being dropped causes degraded throughput performance of window-based protocols (like TCP) for these rate-exceeded modems because of the timeouts and retransmits that follow.

Upstream grant shaping is on a per-CM (SID) basis. The grant shaping feature is a configurable option for the current upstream token-bucket rate-limiting algorithm.

A traffic shaping feature is restricted QoS class assignment, which allows a CMTS administrator to override the class of service provisioned for a CM. When this feature is enabled, the user-defined QoS profile is enforced on the CM attempting to register with the CMTS, regardless of the CM's provisioned class of service. Use the **cable qos profile** command to configure a QoS profile.

Note The restricted QoS class assignment feature is added to address instances where a cable operator implemented rate limiting incorrectly. The feature allows an administrator to override the statically provisioned QoS parameters of the CM and force the CM to use a specific QoS profile defined at the CMTS.

For configuration task information on upstream traffic shaping, refer to the "Setting Upstream Rate Limiting" section on page 3-26.

Downstream Traffic Shaping

The CMTS supports basic downstream traffic shaping by effecting data rate limiting on a per-modem basis. A downstream traffic shaping feature called downstream rate limiting with type-of-service (ToS) bits extends that capability by allowing the CMTS administrator to configure the ToS byte to calculate the data rate for a specified flow.

Downstream rate limiting with ToS bits enables you to partition downstream traffic for a CM into multiple classes of service and multiple data rates by using the three precedence bits in the ToS byte in the IP header to specify a class of service assignment for each packet. Those packets with the precedence bit set in the ToS field are given higher priority. Using the ToS byte, you can calculate the data rate for a specified flow, in addition to the data rate configured on a per-CM basis. By specifying a maximum data rate for a particular ToS, you can override the common maximum downstream data rate.

The administrator can override the maximum common downstream data rate limits by configuring the ToS byte.

Note Packets that contain ToS bytes that have not been configured for downstream data rates continue to use the common data rate limits.

Frequency Hopping Capabilities

Noise in the upstream transmission line, that is from the consumer to the service provider, can degrade data transmission from the subscriber's home. If the noise impairment is of substantial duration, it may cause the cable modem to temporarily lose communication with the headend facility. As a contingency plan, the multiple service operators (MSOs) can reserve multiple channels or upstream frequencies for their subscribers. If one channel suffers too much interference, the CMTS requests that the cable modems "hop" to another channel.

To provide frequency hopping capability, Cisco routers contain a spectrum manager that continuously monitors the noise in unused upstream channels. If the CNR reaches an unacceptable level on a particular channel, the spectrum manager automatically assigns a new upstream channel to the cable modem using that channel.

Cisco routers using Cisco uBR-MC11C, Cisco uBR-MC12C, Cisco uBR-MC14C, and Cisco uBR-MC16C cable interface line cards support the following techniques for upstream frequency hopping when the frequency band in use is not clean:

- Guided frequency hopping—In guided frequency hopping, the spectrum manager automatically assigns a new upstream channel frequency when a configurable threshold of station maintenance (keepalive) messages fails. Failed station maintenance messages represent an impairment of the upstream channel due to noise, plant, or equipment failure. Explicit frequency subbands and associated input power levels are assigned in a spectrum group in guided frequency hopping.

  Note Guided frequency hopping used to be called blind frequency hopping in previous documents.

- Time scheduled frequency hopping—Frequency reassignment is based on the time of every day or a specific day of the week.
- Combined guided and time-scheduled frequency hopping.

Note Frequency hopping is not effective against broadband noise phenomena such as impulse noise.

Time-scheduled and guided hopping techniques are independent concepts:

- The spectrum is controlled by a script, not a frequency table.
- The available spectrum is time-scheduled as an option.
- A guided hopping frequency is selected from the available spectrum at the current time.

You can configure and activate frequency hopping by using spectrum groups. You can create up to 32 cable spectrum groups, each containing multiple upstream ports. The configured channel width is used for each upstream frequency.

After you have created one or more spectrum groups for your cable network, you can add characteristics to them, providing you with more definitive control over frequency usage and frequency hopping.

You can configure hopping thresholds. For example, the frequency hop threshold percentage method prevents a single failing cable modem from affecting service to other working cable modems. As long as a high enough threshold is configured, the system does not hop endlessly due to one cable modem failing to respond to 90 percent of its station maintenance (keepalive) messages.

You can also configure the minimum period between frequency hops, with a default setting of 300 seconds. If the destination channel is expected to be impaired, the minimum period between frequency hops can be reduced to a small value such as 10 seconds. This allows the frequency hop to continue more rapidly until a clear channel is found. If excessive frequency hop is an issue, the minimum period between hops can be increased.

To configure different techniques of frequency hopping, see the "Configuring Spectrum Group Characteristics" section on page 3-28.

Note Spectrum management is not supported for one-way (telco return) cable modems, because spectrum management capabilities focus on the upstream path over an HFC network.

Guided Frequency Hopping

The implementation is known as guided frequency hopping. It is called "guided" because the frequency chosen when hopping is guided by the configured frequencies specified in the spectrum group, which can be either a set of discrete frequencies or a band. In guided frequency hopping, when the CMTS decides to make a frequency hop, it has no "look-ahead" mechanism to tell what the quality of the frequency or band about to be hopped to will be. The lack of "look-ahead" capability is because the Cisco uBR-MC1*x*C cable interface line cards have no built-in spectrum analysis capability. In this case, the search time is 0 seconds and the switching time is 20 ms.

You can specify some rules the system uses when hopping to another frequency when the frequency band in use is not clean. You can assign explicit frequency subbands and associated input power levels in a spectrum group. All cable modems then on the upstream port migrate to the next frequency with an assigned input power level. The number of lost station management messages exceeding a configured threshold can initiate an upstream channel frequency reassignment. For example, you can specify a frequency hop based on lost station management messages that exceed a threshold. The default threshold may be 10-20 percent depending on the Cisco IOS release. The frequency change occurs rapidly without data loss and minimal latency.

Take care to reduce the spectrum allocation when it is used with small channel widths. Otherwise, there will be a large number of upstream channel slots. For example, if the allocation is from 20.0-to-28.0 MHz and an upstream port has its channel width set to 0.2 MHz, there are 40 possible slots for that channel width. Guided frequency hopping can require a long time to find the clean slot, because it tries each available slot, one at a time, for several seconds during each try.

Time-Scheduled Frequency Hopping

You can specify upstream channel frequency reassignment based on a configured time of every day or of a specific day of the week. If your cable plant has an upstream noise characteristic on a weekly cycle, use time-scheduled spectrum allocation. With a time-scheduled policy, a single frequency becomes valid at any given time.

Dynamic Upstream Modulation (SNR-based)

The Dynamic Upstream Modulation feature is supported on the Cisco uBR-MC1*x*C and Cisco uBR-MC16S cable interface line cards beginning with Cisco IOS Release 12.1(3a)EC1, Cisco IOS Release 12.2(4)BC1b, and later releases.

The Dynamic Upstream Modulation feature operates differently on the Cisco uBR-MC16S cable interface line card than on other supported cable interface line cards. See the description of this feature in the "Advanced Hardware-Based Spectrum Management" section on page 3-14 for more information.

Cisco uBR-MC1*x*C (and Cisco uBR-MC16S) cable interface line cards monitor SNR and forward error correction (FEC) counters in the active return path of each upstream port. The Dynamic Upstream Modulation software determines whether upstream channel signal quality can support the modulation scheme configured, and adjusts to the most robust modulation scheme when necessary. When return path conditions improve, this feature returns the upstream channel to the higher modulation scheme that includes the modulation profile.

A modulation profile is a collection of six burst profiles that are sent out in a UCD message to configure modem transmit parameters for the upstream message types: request, request/data, initial maintenance, station maintenance, short grant, and long grant. Dynamic Upstream Modulation adjusts the modulation profiles of an upstream channel based on upstream signal quality.

Dynamic Upstream Modulation can be configured on interfaces with fixed upstream frequencies or on interfaces with assigned spectrum groups.

For a Cisco uBR-MC16C cable interface line card only, the QAM-16 channel can change automatically to a QPSK channel, based on the SNR estimate of the receiver circuitry and FEC correctable/uncorrectable thresholds of a particular upstream channel.

For information on commands to configure Dynamic Upstream Modulation, see "Configuring Dynamic Upstream Modulation" section on page 3-32.

Note The automatic switch of a QAM-16 to QPSK feature is available only on Cisco uBR-MC16C and Cisco uBR-MC16S cable interface line cards.

For example, if you configure Dynamic Upstream Modulation on the Cisco CMTS using modulation profiles 1 and 2, where:

- Modulation profile 1 is the primary modulation profile using QAM-16

  Modulation profile 1 (QAM-16) uses the more bandwidth-efficient modulation scheme and has a higher throughput than modulation profile 2 (QPSK).
- Modulation profile 2 is the secondary modulation profile using QPSK

  Modulation profile 2 (QPSK) uses the more robust modulation scheme, but it is not bandwidth-efficient.

Note Cisco recommends that the primary profile uses QAM-16 modulation and the secondary uses QPSK, but this is optional. The two modulation profiles can both be QPSK or QAM-16. It is not mandatory that one is QAM-16 and the other QPSK, but modulation profile switchover is tied to QAM-16 and QPSK thresholds.

The criteria for modulation profile 1 to switch to modulation profile 2 (more robust modulation scheme) includes one of the following:

- The upstream SNR goes below 25dB (SNR < 25dB)

  OR

- The number of correctable FEC errors is more than 3 percent of the packets received in a 15-second time period

  OR

- The number of uncorrectable FEC errors is more than 1 percent of the packets received in a 15-second time period.

The criteria for modulation profile 2 to switch to modulation profile 1 includes all of the following:

- The upstream SNR is above 28dB (SNR > 28dB)

  AND

- The number of correctable FEC errors is less than 3 percent of the packets received in a 15-second time period

  AND

- The number of uncorrectable FEC errors is less than 1 percent of the packets received in a 15-second time period.

In the previous example, modulation profile 1 switches to modulation profile 2 based on OR conditions. Modulation profile 2 switches to modulation profile 1 based on AND conditions.

Input Power Levels

Upstream input power level modifications were made in Cisco IOS Releases 12.0(6)SC, 12.1(1), 12.1(1)T, 12.1(2)EC1, and 12.2(4)BC1b. The input power level, *power-level-dBmV,* is an option in the **cable spectrum-group** command. The option allows you to specify the expected U.S. input power levels on the upstream receivers on the CMTS when the cable modems are hopping from one fixed frequency to another or from one band to another. Each upstream frequency has an associated upstream input power level in dBmV. The power level is the modem transmit power that each spectrum group can use when an upstream frequency change is necessary. The input power level may be set at the time of the frequency hop.

Specifying an input power level is done so that the cable modems do not have to increase or decrease their transmit power with every hop. The cable operator can perform minor power equalizations as a function of frequency. The valid range is –10 to +10dBmV. The power level value should be changed only if you want to change the power level as part of spectrum management. Some cable plants may want to change only the input power level and not the frequency on a daily time schedule.

For information on how to configure input power levels, see the "Setting Input Power Level" section on page 3-34.

Advanced Hardware-Based Spectrum Management

The Cisco uBR-MC16S cable interface line card is a card with a DOCSIS-based cable interface that supports one downstream and six upstreams. It incorporates a daughter board with hardware-based spectrum management features that provide enhancements to the basic features supported by the other Cisco cable interface line cards.

Note The Cisco uBR10012 universal broadband router using Cisco IOS Release 12.2(8)BC2 and the Cisco uBR-LCP2-MC16S cable interface line card supports a subset of these features. See the "Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support" section on page 3-19 for more details.

Intelligent Spectrum Management Enhancements

Initial Intelligent spectrum management enhancements to the Cisco uBR-MC16S line card were introduced in the Cisco IOS Release 12.1 EC train. Initial support for the Cisco uBR-MC16S card also appeared in Cisco IOS Releases 12.0(7)XR3, 12.1(1a)T1, 12.1(2)EC, 12.2(8)BC2, and included the following features:

- Integrates a DOCSIS cable interface line card with an onboard spectrum analyzer that continuously analyzes the upstream spectrum quality in the DOCSIS frequency range of 5 to 42 MHz.
- Includes hardware-assisted frequency hopping, providing for more intelligent and faster frequency selection than software-only solutions.
- Reduces the response time to ingress noise that could cause modems to drop offline.
- Eliminates blind frequency hopping by initiating frequency hops to known clean channels.
- Improves frequency agility to help eliminate dropped packets and thereby maintain full upstream data rates.
- Supports frequency agility in dense-mode combining environments across a shared spectrum.
- Restricts frequency hopping to a set of discrete fixed frequencies or to a range of frequencies, as desired.
- Allows frequency hop conditions to be customized for specific plant environments and requirements.
- Optionally schedules frequency hops to take advantage of known usage patterns or plant conditions.
- Optionally dynamically reduces channel width to allow cable modems to remain online, even in noisy upstream conditions.
- The Cisco uBR-MC16S cable interface line card can be installed in existing deployments of the Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR universal broadband routers. The Cisco uBR-LCP2-MC16S line card can be installed in Cisco uBR10012 universal broadband routers running Cisco IOS Release 12.2(8)BC2 or later software releases.
- As is the case with the other cable interface line cards, the Cisco uBR-MC16S line card supports online insertion and removal (OIR), allowing for hot-swappable upgrades and maintenance.

Advanced Spectrum Management Features

The Advanced spectrum management features for the Cisco uBR-MC16S cable interface line card are available in 12.2(8)BC2 and later 12.2 BC releases as a software-only upgrade. These enhancements provide the following additional features.

- Supports proactive channel management, to avoid the impacts of ingress and keep subscribers online and connected.
- Offers flexible configuration choices, allowing users to determine the priority of the actions to be taken when ingress noise on the upstream exceeds the allowable thresholds. The configurable actions are frequency hopping, switching the modulation profile, and reducing the channel width.
- Performs carrier-noise ratio (CNR) calculations using Digital Signal Processor (DSP) algorithms in real-time on a per-interface and a per-modem basis.

  Note In Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases, the CNR value is typically more accurate than the SNR value because the CNR value is an estimate calculated on a per modem basis, while the SNR value is a general estimate for the entire upstream. For this reason, the CNR and SNR values might not exactly match for any particular period.

- Intelligently determines when to modify the frequency, channel width, or modulation profile, based on CNR calculations in the active channel and the number of correctable FEC errors and uncorrectable FEC errors. Frequency hopping, channel width change, or profile change occurs in the following circumstances:
  - The CNR value falls below the user-defined threshold value for the primary modulation profile;

    AND
  - Either the correctable FEC error value exceeds its user-defined threshold,

    OR
  - The uncorrectable FEC error value exceeds its user-defined threshold.

  This approach helps avoid unneeded channel changes due to transient noise problems that do not actually cause any errors in the data stream. The channel changes only when noise both affects the CNR of the upstream and generates an unacceptable number of FEC errors in the data. If you want channel changes to occur only in response to the CNR, you can set the FEC error threshold values to zero.

  Separate CNR threshold values are configured for the primary and secondary modulation profiles. When the upstream has moved to the secondary modulation profile, further frequency hopping or channel width changes occur only when the CNR value falls below the user-defined threshold value for the secondary profile.

  Note Previously, channel hopping occurred when the number of missed station maintenance polls exceeded a user-defined threshold or the SNR reported from the Broadcom chip exceeded a certain threshold.

- Enhances the Dynamic Upstream Modulation feature for the Cisco uBR-MC16S line card. This feature supports dynamic modulation using two upstream profiles. The primary profile (typically using QAM-16 “mix” modulation) remains in effect at low noise conditions, but if upstream conditions worsen, the cable modems switch to the secondary profile (typically using QPSK modulation) to avoid going offline. When the noise conditions improve, the modems are moved back to the primary profile.

Note The Dynamic Upstream Modulation feature was introduced in Cisco IOS Release 12.1(3a)EC1. The above enhancements to this feature exist only in Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases; they are not supported in any Cisco IOS 12.1 EC Release.

- When using a Cisco uBR-MC16S line card on a Cisco CMTS router running Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases, the spectrum management hardware uses the real-time CNR readings from the DSPs onboard the Cisco uBR-MC16S line card instead of the signal-to-noise ratio (SNR) values from the Broadcom 3137 chip to determine the signal quality of the upstream channel. The CNR value is a more accurate description of noise conditions on the upstream.
- Provides an SNMP interface so that a network management workstation or other graphical tool can obtain spectrum information for either a particular cable modem or for an entire upstream. The frequency resolution can be as fine as 12 KHz.

Note The CISCO-CABLE-SPECTRUM MIB has been enhanced to provide this support.

- Supports the DOCSIS Cable Modem Test Analyzer (DCMTA) from Acterna. The DCMTA software provides spectrum analyzer capability for an individual upstream port or an individual cable modem. Spectrum data is extracted from the Cisco uBR-MC16S cable interface line card using SNMP, allowing for live troubleshooting of an upstream port or individual cable modem. The DCMTA software supports simultaneous client access to a single or multiple CMTS, upstreams, or cable modems.

Note To contact Acterna about the DCMTA software, call 1-800-638-2049 or +1-301-353-1550, or visit http://www.acterna.com.

Benefits

The spectrum management features provided on the Cisco CMTS router platforms provide several key system benefits:

- Improves response time to ingress noise impairments that appear in the upstream return path.
- Boosts the percentage of modems online.
- Mitigates the impact of ingress to subscriber services.
- Saves time and effort by MSO operations staff when troubleshooting minor plant outages.
- Increases cable plant reliability.
- Maximizes spectrum utilization.

Table 3-3 summarizes the specific benefits of the Guided and Scheduled spectrum management features that are supported for all Cisco CMTS router platforms.

Table 3-3 Benefits of Guided and Scheduled Spectrum Management Features

Guided and Scheduled Spectrum Management Feature	Benefits
Upstream Traffic Shaping	• The CMTS can buffer the grants for rate-exceeded modems. This grant buffering at the CMTS avoids TCP-related timeouts and retransmits, resulting in an improved TCP throughput performance for the rate-exceeded modems. Thus, traffic shaping enables the CMTS to enforce the peak upstream rate for the modem without degrading overall TCP performance for the modem.
Downstream Traffic Shaping	• Allows users to configure multiple data rates (defined by the value of the IP precedence bits in the ToS byte) for a given modem. By specifying a maximum data rate for a particular ToS, users can override the common maximum downstream data rate.
Input Power Levels	• Allows the cable plant operator to perform minor power level equalization as a function of frequency.
Frequency Hopping Capabilities	• Proactively countermeasures upstream noise impairments by assigning a new upstream channel to the cable modem. MSOs can take advantage of this feature especially when they have less than an optimal carrier-to-noise ratio in the upstream frequencies or when their cable plants exhibit random bursts of ingress noise that affect reliability.
Dynamic Upstream Modulation	• Reduces the risk associated with transitioning to QAM-16 modulation in the return path and provides assurance that subscribers remain online and connected during return path impairments. • Checks that the active upstream signal quality can support the configured modulation scheme and proactively adjusts to the more robust modulation scheme when necessary. • Eliminates the necessity to hop channels for cable modems to stay online by automatically switching from the primary modulation profile to the secondary modulation profile.

Table 3-4 summarizes the specific benefits of the Advanced spectrum management features that are supported on Cisco CMTS routers using the Cisco uBR-MC16S cable interface line card.

Table 3-4 Benefits of Advanced Spectrum Management Features (Cisco uBR-MC16S Card)

Advanced Spectrum Management Feature	Benefits[1]
Hardware-Assisted Spectrum Management	• Offloads much of the spectrum management processing from the main system processor to the Digital Signal Processing (DSP) hardware onboard the Cisco uBR-MC16S line card, freeing up the main processor for other duties.
Dynamic Channel Width Change	• Imrpoves the DOCSIS upstream channel availability by finding the maximum possible channel width for an upstream when noise conditions make the current channel width unusable. • Provides the maximum RF spectrum utilization efficiency for current plant conditions. • Customizable range of channel widths that can be used to respond to noise problems.

Table 3-4 Benefits of Advanced Spectrum Management Features (Cisco uBR-MC16S Card) (continued)

Advanced Spectrum Management Feature	Benefits[1]
Intelligent Frequency Hopping	• Proactively changes upstream frequency for an interface before noise conditions become severe enough to force cable modems offline. • Dedicated hardware intelligent performs “look-ahead” to choose new upstream frequency to find a stable channel. • Flexible priority configuration allows hopping decision criteria to be tailored to the individual cable plant environment. • Improves responsiveness to ingress impairments, by matching the hopping decision criteria to the fluctuating plant conditions. • Pinpoints CNR variations with per-modem accuracy to isolate problematic cable modems. • Sustains or even improves subscriber online percentages through user-programmable proactive channel management techniques.
Dynamic Upstream Modulation	• Reduces the risk associated with switching between QPSK and QAM-16 modulation in the upstream to respond to ingress noise, so that subscribers remain online and connected. • Checks the current upstream signal to ensure that it can support the configured modulation scheme, and proactively adjusts to the secondary, more robust modulation scheme when necessary. • Improves DOCSIS upstream channel availability and provides maximum RF spectrum utilization efficiency. • Eliminates unnecessary frequency hopping by switching modulation profiles to one that allows cable modems to remain online while using the currently assigned upstream. • Provides assurance that subscribers remain online and connected during periods of return path impairments
SNMP Interface	• Provides a way to remotely obtain the current status of noise on an upstream. This information can then be inserted into third-party or custom reporting and graphing applications. • Provides visibility to ingress and impulse noise under the carrier frequency on a per-port basis. • Provides an easy-to-use, distributed method to remotely gather real-time display of the DOCSIS upstream spectrum for individual cable modems and set-top boxes (STBs). • Reduces the reliance on costly spectrum analyzers at every headend or hub. • Quickly provides spectrum views through an intuitive interface, without the complicated setup time of a spectrum analyzer. • Allows the technician to troubleshoot the network remotely, as opposed to having to be physically present to connect and use a spectrum analyzer. • Supports the DOCSIS Cable Modem Test Analyzer (DCMTA) from Acterna Corp.

1. The Cisco uBR10012 universal broadband router using Cisco IOS Release 12.2(8)BC2 supports a subset of these features. See the “Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support” section on page 3-19 for more details.

Restrictions and Limitations

Dynamic Upstream Modulation

- The Cisco router has one preconfigured (primary) modulation profile that defines a typical profile for QPSK modulation. To use the Dynamic Upstream Modulation feature, you must create a second modulation profile that has a higher modulation scheme than the preconfigured profile.
- Upstream modulation profiles are assigned to upstream ports and affect all cable modems on those upstream ports.
- Modulation profiles affect the physical layer of the cable network, so only trained technicians who are familiar with the DOCSIS specifications should create modulation profiles.
- When using the Dynamic Upstream Modulation feature with Voice over IP (VoIP) services, frequent changes to the upstream modulation or channel width could briefly impact the quality of voice calls
- The Dynamic Upstream Modulation feature operates differently on the Cisco uBR-MC16S cable interface line card than on other supported cable interface line cards. See the description of this feature in the "Guided and Scheduled Spectrum Management" section on page 3-7 and the "Advanced Hardware-Based Spectrum Management" section on page 3-14 for more information.

Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support

The Cisco uBR10012 router using the Cisco uBR-LCP2-MC16S cable interface line card and Cisco IOS Release 12.2(8)BC2 has the following restrictions and limitations:

- Frequency hopping is based on the carrier-to-noise ratio (CNR) and the correctable FEC error and uncorrectable FEC error values. A channel will frequency hop if the CNR falls below the configurable threshold AND either the correctable or uncorrectable FEC error values exceed the configurable threshold values.

  Use the **cable upstream threshold** command to change these values. In Cisco IOS Release 12.2(8)BC2, the CNR threshold for the primary modulation profile defaults to 25 dB. The CNR threshold for the secondary modulation profile defaults to 15 dB. The correctable FEC error threshold defaults to 1 percent of total packets received, and the uncorrectable FEC error threshold defaults to 1 percent of total packets received.

  Note In releases previous to Cisco IOS Release 12.2(8)BC2, the channel would hop if either the CNR fell below the configurable threshold OR either the correctable or uncorrectable FEC error values exceeded the configurable threshold values. If you are using only one modulation profile (QPSK), you might need to reduce the CNR threshold value and increase the correctable FEC error value to prevent undesired frequency hopping.

- Fixed-frequency spectrum groups are not supported.
- Shared spectrum groups are not supported.
- In Cisco IOS Release 12.2(8)BC2, the short and long grant bursts of the pre-configured **mix** and **qam-16** modulation profiles (see the **cable modulation-profile** command) default to a unique word offset of 8 (uw8). These values should be changed to **uw16** for optimal performance. This can be done with the following commands:

```
cable modulation-profile n short 6 75 6 8 16qam scrambler 152 no-diff 144
fixed uw16
cable modulation-profile n long 8 220 0 8 16qam scrambler 152 no-diff 160
fixed uw16
```

Note This default is being tracked by caveat CSCdx35070.

- When using Cisco IOS Release 12.2(8)BC2, in rare situations, using CLI commands to configure the Cisco uBR-LCP2-MC16 card could result in the error message "Resources are busy with other msg requests. Try later." The workaround is to repeat the same configuration command again until the error disappears.

Cisco uBR-MC16S Line Card

- The initial Intelligent spectrum management enhancements to the Cisco uBR-MC16S line card were introduced in the Cisco IOS Release 12.1 EC train. The Advanced spectrum management features, including CNR-based proactive frequency hopping, require Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases.
- The Cisco uBR-MC16S line card is supported on the Cisco uBR7200 series routers and on the Cisco uBR10012 router. It is not supported on Cisco uBR7100 series router.
- The Cisco uBR-MC16S line card is not supported in any release of Cisco IOS Release 12.0SC.
- Upstream channels must meet the CNR and carrier-to-ingress power ratio values given in the DOCSIS specifications. The minimum value for both parameters is 25 dB in the 5–42 MHz frequency range.
- The Advanced Spectrum Management features do not support shared spectrum groups, requiring that each upstream port on the Cisco uBR-MC16S line card must have its own RF domain (a unique set of non-overlapping frequencies).
- HCCP 1+1 redundancy is not supported on any cable interface line card that has defined spectrum groups, which typically is the normal configuration for the Cisco uBR-MC16S line card.

Fixed-Frequency Spectrum Groups with the Cisco uBR-MC16S Card

When using the Cisco uBR-MC16S cable interface line card, do not configure fixed-frequency spectrum groups by specifying a single frequency using the **cable spectrum-group frequency** command (for example, **cable spectrum-group 3 frequency 76000000**). If single-frequency spectrum groups are desired, configure a band with a starting and ending range, which, along with the desired channel width, specifies the desired center frequency. In this situation, you must also configure a static channel width so that the Dynamic Upstream Modulation feature does not attempt to hop to a different frequency using a smaller channel width.

For example, to specify a center frequency of 7.6 MHz with a 3.2 MHz channel width, specify a starting frequency of 6.0 MHz (7.6 MHz - 1.6 MHz) and an ending frequency of 9.2 MHz (7.6 MHz + 1.6 MHz):

```
CMTS(config)# cable spectrum-group 15 band 6000000 9200000
CMTS(config)# int c6/0
CMTS(config-if)# cable upstream 0 channel-width 3200000 3200000
CMTS(config-if)# cable upstream 0 spectrum-group 15
```

Note Cisco IOS Release 12.2(8)BC2 does not support fixed-frequency spectrum groups.

DOCSIS Cable Modem Test Analyzer

Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases and the Cisco uBR-MC16S cable interface line card support the DOCSIS Cable Modem Test Analyzer (DCMTA) software from Acterna Corp. This spectrum management tool is designed for troubleshooting ingress and other problems on the return path in real time, not for ongoing monitoring of the upstream spectrum.

Constant use of the DCMTA tool could result in excessive volumes of SNMP traffic that affects network bandwidth and performance on the Cisco uBR7200 series CMTS. For this reason, Cisco recommends against running the DCMTA software continuously. Instead, start the software when needed and exit it after the problem has been resolved.

HCCP 1+1 and N+1 Redundancy Support for the Cisco uBR-MC16S Cable Interface Line Card

Cisco IOS Release 12.1(7)EC adds support for the Cisco uBR-MC16S cable interface line card when used in an HCCP 1+1 redundant configuration. Previously, the Cisco uBR-MC16S card could be used in a redundant configuration only by first disabling its intelligent spectrum management features.

In Cisco IOS Release 12.1(7)EC and later, the Cisco uBR-MC16S card can be used as the protect cable interface or working cable interface, with either another Cisco uBR-MC16S card or a Cisco uBR-MC16C card. Table 5 shows how a switchover in each of these configurations affects the Intelligent spectrum management features of the Cisco uBR-MC16S card.

Table 5 Switchover Operation for a Cisco uBR-MC16C/Cisco uBR-MC16S Configuration

Working Cable Interface	Protect Cable Interface	Operation After Switchover
Cisco uBR-MC16C	Cisco uBR-MC16S	The protect card (Cisco uBR-MC16S) uses the same upstream frequency as the working card, but after the system stabilizes, the protect card begins using the Intelligent spectrum management features of the Cisco uBR-MC16S card, as configured on the protect CMTS.
Cisco uBR-MC16S	Cisco uBR-MC16C	The protect card (Cisco uBR-MC16C) uses the same upstream frequency as the working card. If the upstream becomes unstable, the Cisco uBR-MC16C performs only guided frequency hopping.
Cisco uBR-MC16S	Cisco uBR-MC16S	The protect card initially uses the same upstream frequency as the working card, but after the system stabilizes, the protect card continues using the Intelligent spectrum management features of the Cisco uBR-MC16S card.

Note HCCP 1+1 or N+1 support for the Cisco uBR-MC16S card exists only in Cisco IOS Release 12.1(7)EC or later 12.1 EC release and in Cisco 12.2(8)BC2 or later 12.2 BC release. Therefore you cannot use the Advanced spectrum management features in Cisco IOS Release 12.1(7)CX with an HCCP 1+1 or N+1 redundant configuration.

Prerequisites

- The appropriate Cisco IOS release for the desired features. For a list of supported Cisco IOS releases by feature, see Table 3-2 on page 3-8.
- For Guided and Scheduled spectrum management features, Cisco uBR-MC11C, Cisco uBR-MC12C, Cisco uBR-MC14C, Cisco uBR-MC16, and Cisco uBR-MC28C cable interface line cards.

- For Intelligent and Advanced spectrum management features (hardware-based, CNR frequency hopping), Cisco uBR-MC16S cable interface line card (Cisco uBR7200 series routers) or Cisco uBR-LCP2-MC16S cable interface line card (Cisco uBR10012 routers).
- Ensure that your network is designed to support reliable broadband data transmission. At minimum, your network must include:
  - A Dynamic Host Configuration Protocol (DHCP) server to assign IP addresses to cable modems or set-top boxes on the hybrid fiber-coaxial (HFC) network. This can be a server on the WAN side of the Cisco uBR7200 series router or a Cisco CMTS router that has been configured to act as the DHCP server.
  - If you are not using the Cisco uBR7100 series router with integrated upconverter, you must install the appropriate IF-to-RF external upconverter between the Cisco CMTS router and the combiner.

Note The term "combiner" refers to all cables, amplifiers, and taps at the headend or cable distribution center that connect the Cisco CMTS router to the HFC network.

  - Diplex filters installed in the downstream RF path between the cable modems and the cable interface cards in the router. RG-59 headend coaxial cable with the maximum braid available (60 percent + 40 percent braid), double foil, and the correct connector for this cable.
- Avoid frequencies with known ingress problems such as amateur radio bands or short-wave bands.
- Avoid hostile spectrums below 20 MHz.
- When designing your channel plan, allow extra bands for frequency hopping.
- Place upstream ports in the same combiner group in a shared spectrum group.
- Use the receive power level setting to perform slight equalization adjustments.
- Due to the nature of CATV technology, upstream noise management is a significant issue. Cisco recommends that you follow the rigorous North American plant maintenance procedures that are documented in the *NCTA Supplement on Upstream Transport Issues* to adjust return amplifiers and lasers.

Related Documents

IOS Documents

- *Cisco IOS Multiservice Applications Configuration Guide,* Release 12.1
- *Cisco IOS Multiservice Applications Command Reference,* Release 12.1

Cisco uBR7100 Series Universal Broadband Routers

- *Cisco uBR7100 Series Universal Broadband Router Hardware Installation Guide*
- *Cisco uBR7100 Series Universal Broadband Router Software Configuration Guide*

Cisco uBR7200 Series Universal Broadband Routers

- *Cisco uBR7200 Series Universal Broadband Router Hardware Installation Guide*

- *Cisco uBR7200 Series Universal Broadband Router Software Configuration Guide*
- *Cisco uBR7200 Series Universal Broadband Router Cable Modem Card Installation and Configuration* publication
- *Cisco uBR7200 Series Universal Broadband Router Port Adapter Installation and Configuration* publication
- *Cisco uBR7200 Series Universal Broadband Router 550-Watt DC-Input Power Supply Replacement Instructions*
- *Cisco uBR7200 Series Universal Broadband Router Subchassis and Midplane Replacement Instructions*
- *Cisco uBR7200 Series Rack-Mount and Cable-Management Kit Installation Instructions*
- *Cisco uBR7200 Series Universal Broadband Router Fan Tray Replacement Instructions*
- *Cisco uBR7200 Series Universal Broadband Router Feature Enhancements* publication

Cisco uBR10012 Universal Broadband Routers

- *Cisco uBR10012 Series Universal Broadband Router Hardware Installation Guide*
- *2400W AC-Input Power Shelf for the Cisco uBR10000 Series Universal Broadband Router*
- *Cable Interface Line Card Processor Hardware Installation for the Cisco uBR10000 Series Universal Broadband Router*
- *Fan Assembly Module for the Cisco uBR10000 Series Universal Broadband Router*
- *DC Power Entry Module for the Cisco uBR10000 Series Universal Broadband Router*
- *Performance Routing Engine Card Hardware Installation for the Cisco uBR10000 Series Universal Broadband Router*
- *TCC+ Card for the Cisco uBR10000 Series Universal Broadband Router*

Spectrum Management Documents

This document supersedes the previous spectrum management documents that have been published. The following documents are still available but should be used with caution, because they are not updated or corrected when changes are made to the supported Cisco CMTS platforms or to the Cisco IOS software.

- *Amplitude Averaging Compensation on the Cisco uBR7200 Series Cable Router*
- *Blind Hopping Support on the MC16S Modem Card for the Cisco uBR7200 Series Cable Router*
- *Cisco uBR7246 Universal Broadband Router Feature Enhancements* (see the **spectrum-group** commands)
- *Cisco uBR7200 Series Universal Broadband Router Dynamic Upstream Modulation*, Release 12.1
- *Cisco uBR7200 Series Universal Broadband Router MC16S Cable Modem Card Spectrum Management*
- *Enhanced-Spectrum Management and Telephone Return for the Cisco uBR7200 Series Cable Router*
- *Advanced Spectrum Management Features for the Cisco uBR-MC16S Spectrum Management Card*
- *"Configuring and Activating Frequency Agility"* section in the "Understanding System Operations" chapter in the *Cisco uBR7200 Series Universal Broadband Router Software Configuration Guide*.

Supported Platforms

Table 3-6 Spectrum Management Features and Supported Platforms

Feature	Supported Platform
Upstream Traffic Shaping	• Cisco uBR7100 series • Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR • Cisco uBR10012 router
Frequency Hopping Capabilities	• Cisco uBR7100 series • Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR • Cisco uBR10012 router
Input Power Levels	• Cisco uBR7100 series • Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR • Cisco uBR10012 router
Dynamic Upstream Modulation (SNR-based)	• Cisco uBR7100 series • Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR with Cisco uBR-MC1xC and Cisco uBR-MC28C cable interface line cards • Cisco uBR10012 router with Cisco uBR-LCP2-MC16C, Cisco uBR-LCP2-MC16E, Cisco uBR-LCP2-MC16S, and Cisco uBR-LCP2-MC28C cable interface line cards
Dynamic Upstream Modulation (CNR hardware-based)	• Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR with Cisco uBR-MC16S cable interface line card
Advanced Spectrum Management Features	• Cisco uBR7223, Cisco uBR7246, and Cisco uBR7246 VXR with Cisco uBR-MC16S cable interface line card • Cisco uBR10012 router with Cisco uBR-LCP2-MC16S cable interface line card[1]

1. The Cisco uBR10012 router supports a subset of the advanced spectrum management features when using Cisco IOS Release 12.2(8)BC2 and the Cisco uBR-LCP2-MC16S cable interface line card. See the "Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support" section on page 3-19 for more details.

Feature Navigator

Feature Navigator is a web-based tool that enables you to quickly determine which Cisco IOS software images support a specific set of features and which features are supported in a specific Cisco IOS image. To access Feature Navigator, you must have an account on Cisco.com. If you have forgotten or lost your account information, e-mail the Contact Database Administration group at cdbadmin@cisco.com. If you want to establish an account on Cisco.com, go to the *User Registration* web page on Cisco.com and follow the directions to establish an account.

Feature Navigator is updated when major Cisco IOS software releases and technology releases occur. As of July 2002, Feature Navigator supports the following Cisco IOS release trains: 11.2, 11.2P, 11.3, 11.3T, 12.0, 12.0S, 12.0ST, 12.0T, 12.1, 12.1E, 12.1T, 12.2, 12.2T.

Access the *Cisco IOS Feature Navigator* on Cisco.com.

Supported Standards, MIBS, and RFCs

Standard

DOCSIS 1.0 (SP-RFI-I05-991105)

DOCSIS 1.1 (SP-RFIv1.1-I06-001215)

MIBs

- These features support the standard MIBs supported by the Cisco uBR7100 series, Cisco uBR7200 series, and the Cisco uBR10012 router, including the DOCSIS 1.0 and 1.1 MIBs
- CISCO-CABLE-SPECTRUM-MIB

  To obtain lists of supported MIBs by platform and Cisco IOS release, and to download MIB modules, go to the *Cisco Network Management Software* web page (MIBs sections) on Cisco.com.

RFCs

No new or modified RFCs are supported by this feature.

Configuration Tasks

This section describes the configuration tasks that are most commonly performed when using the spectrum management features on the Cisco CMTS platforms. See the following sections for the configuration tasks that are appropriate for your platform and cable interface line cards.

- "Guided and Scheduled Spectrum Management Configuration Tasks" section on page 3-25—Configures spectrum management for all Cisco CMTS platforms and the Cisco uBR-MC1xC, Cisco uBR-MC16E, and Cisco uBR-MC28C cable interface line cards.
- "Advanced Spectrum Management Configuration Tasks (Cisco uBR7200 Series)" section on page 3-36—Configures spectrum management for the Cisco uBR7200 series routers with the Cisco uBR-MC16S cable interface line card.
- "Advanced Spectrum Management Configuration Tasks (Cisco uBR10012)" section on page 3-44—Configures spectrum management for the Cisco uBR10012 routers with the Cisco uBR-LCP2-MC16S cable interface line card.

Guided and Scheduled Spectrum Management Configuration Tasks

The following tasks configure the Guided and Scheduled spectrum management features that are supported on all Cisco CMTS platforms using the Cisco uBR-MC1xC, Cisco uBR-MC16E, and Cisco uBR-MC28C cable interface line cards.

- Setting Upstream Rate Limiting, page 3-26
- Setting Downstream Rate Limiting, page 3-27
- Creating Spectrum Groups, page 3-28
- Configuring Spectrum Group Characteristics, page 3-28
- Assigning the Spectrum Group and the Upstream Ports, page 3-32

Setting Upstream Rate Limiting

Upstream rate limiting allows upstream bandwidth requests from rate-exceeding cable modems to be buffered without incurring TCP-related timeouts and retransmits. This enables the CMTS to enforce the peak upstream rate for each cable modem without degrading overall TCP performance for the subscriber customer premises equipment (CPE) devices. Upstream grant shaping is per SID.

Token-bucket policing with shaping is the per-upstream default rate-limiting setting at the CMTS. Shaping can be enabled or disabled for the token-bucket algorithm.

To enable upstream rate limiting for an upstream port on a Cisco cable interface line card, use one of the following commands in cable interface configuration mode.

	Command	Purpose
Step 1	`CMTS01(config-if)# cable upstream` *usport* `rate-limit`	Enables rate limiting for the specified upstream port.
	`CMTS01(config-if)# cable upstream` *usport* `rate-limit token-bucket`	Enables rate limiting for the upstream port employing the token-bucket policing algorithm. With this command the CMTS automatically drops packets in violation of allowable upstream bandwidth.
	`CMTS01(config-if)# cable upstream` *usport* `rate-limit token-bucket shaping`	Default. Enables rate limiting for the upstream port employing the token-bucket policing algorithm with traffic shaping. Use of the default value (the upstream port's rate limit) enforces strict DOCSIS-compliant rate limiting. The default setting of **token-bucket** with the **shaping** option is recommended.
Step 2	`CMTS01(config-if)# ^Z` `CMTS01#`	Exits back to the EXEC mode so that you can verify upstream rate limiting.

To disable upstream traffic shaping for an upstream port, enter the following command in cable interface configuration mode:

```
CMTS01(config-if)# no cable upstream usport rate-limit
```

For examples of upstream rate limiting, see the "Upstream Traffic Shaping and Rate Limiting Examples" section on page 3-56.

Note For more information on the **cable upstream rate-limit** command, see the *Cisco Broadband Cable Command Reference Guide* on Cisco.com and on the Documentation CD-ROM.

Setting Downstream Rate Limiting

Downstream rate limiting enables you to use the token-bucket policing algorithm with traffic shaping options or the weighted-discard policing algorithm to buffer, shape, or discard packets that exceed a set bandwidth. Downstream rate limiting is disabled by default.

To enable downstream rate limiting for a downstream port on a Cisco cable interface line card, use one of the following commands in cable interface configuration mode.

	Command	Purpose
Step 1	`CMTS01(config-if)# cable downstream rate-limit`	Enables rate limiting on the downstream port using the token-bucket policing algorithm. This is the default when no option is entered.
Step 2	`CMTS01(config-if)# cable downstream rate-limit token-bucket`	Enables rate limiting on the downstream port using the token-bucket policing algorithm. With this command, the CMTS automatically drops packets that are in violation of the allowable bandwidth.
	`CMTS01(config-if)# cable downstream rate-limit token-bucket shaping`	Enables rate limiting on the downstream port using the token-bucket policing algorithm with traffic shaping.
	`CMTS01(config-if)# cable downstream rate-limit token-bucket shaping granularity` *msec*	Enables rate limiting on the downstream port using the token-bucket policing algorithm with specific traffic-shaping time granularity. Acceptable values are 1, 2, 4, 8, or 16 milliseconds.
	`CMTS01(config-if)# cable downstream rate-limit token-bucket shaping max-delay` *msec*	Enables rate limiting on the downstream port using the token-bucket policing algorithm with specific maximum traffic-shaping buffering delay. Acceptable values are 128, 256, 512, or 1028 milliseconds.
Step 3	`CMTS01(config-if)# cable downstream rate-limit weighted-discard` *exp-weight*	Enables rate limiting on the downstream port using the weighted-packet discard policing algorithm and assign a weight for exponential moving average of loss rate. Acceptable values are 1 to 4.
Step 4	`CMTS01(config-if)# ^Z` `CMTS01#`	Exits back to EXEC mode so that you can verify the steps.

To disable downstream traffic shaping for a downstream port, enter the following command in cable interface configuration mode:

```
CMTS01(config-if)# no cable downstream rate-limit
```

For examples of downstream rate limiting, see the "Downstream Traffic Shaping and Rate Limiting Examples" section on page 3-59.

Note For more information on the **cable downstream rate-limit** command, see the *Cisco Broadband Cable Command Reference Guide* on Cisco.com and on the Documentation CD-ROM.

Creating Spectrum Groups

To create a spectrum group with either a specific frequency or a band of frequencies, use one of the following commands in global configuration mode:

Command	Purpose
`CMTS01(config)# cable spectrum-group group-number [time day hh:mm:ss [delete]] frequency up-freq-Hz [power-level-dBmV]`	Creates a spectrum group with a specific frequency.
or	
`CMTS01(config)# cable spectrum-group group-number [time day hh:mm:ss [delete]] band up-freq-Hz up-freq2-hz [power-level-dBmV]`	Creates a spectrum group with a band of frequencies. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32. An upstream frequency has an associated upstream input power level in dBmV. The power level value should be changed only if you want to change the power level as part of spectrum management. The standard power level is 0 dBmV. The **delete** option deletes a frequency. To remove a spectrum group, use the **no cable spectrum-group** command.

Refer to the "Adding an Upstream Frequency" section on page 3-29 and "Adding a Spectrum Band" section on page 3-30 for additional syntax information for the **cable spectrum-group** command.

Tip To troubleshoot the configuration, make sure that you have entered a valid spectrum group number and type.

Configuring Spectrum Group Characteristics

After you have created spectrum groups for your cable network, you can configure the spectrum groups with the following characteristics:

- Adding an Upstream Frequency, page 3-29
- Adding a Spectrum Band, page 3-30
- Setting Frequency Hop Threshold or Minimum Hop Period, page 3-30
- Adding a Shared Spectrum Group, page 3-31

Spectrum group characteristics provide more control over frequency usage and frequency hopping. Configuring spectrum group characteristics enables frequency agility and disables the fixed upstream frequency setting.

The **cable spectrum-group** command is used to configure spectrum group characteristics as well as to create a spectrum group. The complete command is:

```
[no] cable spectrum-group group-number [time day hh:mm:ss] [delete] [{frequency up-freq-hz
[power-level-dbmv]|hop threshold percent|hop period seconds|band up-freq-hz up-freq2-hz
[power-level-dBmV]|shared}]
```

You can use the command to configure all the characteristics at once or enter the parts of the command separately to configure a separate characteristic. Use the **no** form of the command to remove a spectrum group.

Note For more information on the **cable spectrum-group** command and for syntax descriptions, see the *Cisco Broadband Cable Command Reference Guide* on Cisco.com and on the Documentation CD-ROM.

Adding an Upstream Frequency

Before you add a list of upstream frequencies (or frequency hop tables), start by determining which upstream ports are assigned to a combiner group. Refer to the "Determining the Upstream Ports Assigned to a Combiner Group Example" section on page 3-61 for an example.

To add a list of upstream frequencies and optional nominal power levels that each spectrum group can use when an upstream frequency change is necessary, use one of the following commands in global configuration mode:

Command Options (either/or)	Purpose
`CMTS01(config)# cable spectrum-group group-number [delete] frequency up-freq-hz [power-level-dbmv]`	Adds an upstream frequency to the list of valid frequencies with a default power level for a spectrum group. Specifies the center frequency for the given spectrum group for a frequency hop. Entering additional **cable spectrum-group** *group-number* **frequency** commands for the same spectrum group creates a collection of allowable center frequencies for spectrum group hopping. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32. An upstream frequency has an associated upstream input power level in dBmV. The power level value should be changed only if you want to change the power level as part of spectrum management. The standard power level is 0 dBmV. The **delete** option deletes a frequency.
`CMTS01(config)# cable spectrum-group group-number [time day hh:mm:ss] [delete] frequency up-freq-hz [power-level-dbmv]`	Adds an upstream frequency to the spectrum group at a particular time of day and day of the week. The time option specifies a time of day and day of the week on which the CMTS should automatically perform a frequency hop for the given spectrum group. The **delete** option deletes a frequency at a particular time and day. **Note** If the **time** option is configured, the frequency setting is either made available or deleted at the specified time.

Note Each spectrum group should have its own list of upstream frequencies. Valid frequencies are 5,000,000 to 42,000,000 Hz; valid power levels at a channel width of 1.6 MHz are –10 dBmV to 25 dBmV.

Note You must repeat the command described above for each frequency or power level that you want to add to a spectrum group's list of valid values.

Adding a Spectrum Band

To configure a spectrum band of frequencies in addition to frequency entries to support automatic frequency tables, use one of the following commands in global configuration mode:

Command	Purpose
`CMTS01(config)# cable spectrum-group` *group-number* **band** *up-freq-hz up-freq2-hz* [*power-level-dBmV*] or	Adds a band of frequencies to the spectrum group. The band is a range of center frequencies that the CMTS can scan in order to find an acceptable channel to which the spectrum group may hop. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32. An upstream frequency has an associated upstream input power level in dBmV. The power level value should be changed only if you want to change the power level as part of spectrum management. The standard power level is 0 dBmV.
`CMTS01(config)# cable spectrum-group` *group-number* [**time** *day hh:mm:ss*] [**delete**] **band** *up-freq-hz up-freq2-hz* [*power-level-dBmV*]	Adds a band at a particular time of day and day of the week. The **delete** option deletes a band at a particular time and day. **Note** If the **time** option is configured, the frequency setting or band is either made available or deleted at the specified time.

Setting Frequency Hop Threshold or Minimum Hop Period

To adjust the frequency hop threshold percentage or the minimum period between frequency hops, use one of the following commands in global configuration mode:

Command	Purpose
`CMTS01(config)# cable spectrum-group group-number hop threshold percent` or	Sets the percentage of all cable modems losing keepalive messages that will cause a frequency hop. Hop threshold is the threshold value (expressed as a percentage) of the number of offline modems identified before the CMTS initiates an automatic frequency hop. The frequency hop threshold percentage method prevents a single failing cable interface from affecting service to other good cable interfaces. The system does not hop endlessly because one cable interface is generating 90% of the errors and 90% of the traffic. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32.
`CMTS01(config)# cable spectrum-group group-number hop period seconds`	Sets the minimum time between frequency hops in seconds. Valid values are from 1 to 3600 seconds. Hop period specifies the minimum period (in seconds) before which a frequency hop can occur. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32.

To verify frequency hopping on the CMTS, see the "Troubleshooting Spectrum Group Characteristics" section on page 3-36.

Adding a Shared Spectrum Group

To specify that a particular spectrum group is a shared RF spectrum group, use the following command in global configuration mode:

Command	Purpose
`CMTS01(config)# cable spectrum-group group-number shared`	Specifies a given spectrum group as a shared RF spectrum group and tells the CMTS that you want to be sure that upstream frequencies assigned to an upstream port in the spectrum group are not assigned to any other upstream port in the spectrum group. *Group-number* specifies the spectrum group you are adding or specifies the spectrum group you want removed from your router configuration. Valid range is from 1 to 32

To verify a shared spectrum group, see "Verifying Spectrum Group Configuration Example" section on page 3-61.

Assigning the Spectrum Group and the Upstream Ports

After you have added upstream frequencies (hop tables) and you have determined which upstream ports you want assigned to a combiner group, you want to assign the upstream ports to the frequency hop tables for an interface.

To configure a frequency hop table, use the following commands:

	Command	Purpose
Step 1	`CMTS01(config)# interface cable slot/port`	Enters cable interface configuration mode for the interface to which you want to assign a spectrum group.
Step 2	`CMTS01(config-if)# cable spectrum-group group-number`	Assigns the spectrum group to the interface.
Step 3	`CMTS01(config-if)# cable upstream usport spectrum-group group-number`	Assigns the upstream ports to the spectrum group for the interface.
Step 4	`CMTS01(config-if)# no cable upstream port shutdown`	Enables the upstream port.
Step 5	`CMTS01(config-if)# exit`	Exits configuration mode.

Note For help in determining which upstream ports to assign in a combiner group, refer to the example, Determining the Upstream Ports Assigned to a Combiner Group Example, page 3-61.

Tip To display the current allocation table and frequency assignments, use the **show cable spectrum-group** command in privileged EXEC mode.

Configuring Dynamic Upstream Modulation

To create a modulation profile, set modulation profile parameters, select an interface, and add the modulation profile to the interface, use the following commands:

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.

	Command	Purpose
Step 2	`Router(config)# cable modulation-profile` *profile* [**mix** | **qam-16** | **qpsk**]	Creates a modulation profile. A modulation profile is a collection of six burst profiles sent out in a UCD message to configure modem transmit parameters for the upstream message types: request, reqdata, initial maintenance, station maintenance, short grant, and long grant. *profile* = Modulation profile number (1–8). **mix** = Creates a default QPSK/QAM-16 mix modulation profile (short and long grant bursts are sent using QAM-16, while request, initial ranging, and station maintenance bursts are sent using QPSK). **qam-16** = Creates a default QAM-16 modulation profile, where all bursts are sent using QAM-16. **qpsk** = Creates a default QPSK modulation profile, where all bursts are sent using QPSK. Do not use the QAM-16 mode unless you have verified that your cable plant can support that modulation profile. Most cable plants should instead use the **mix** modulation profile for the primary profile.
Step 3	`Router(config)# cable modulation-profile` *profile* [**mix** | **qam-16** | **qpsk**]	Repeat this command to create the secondary profile. Typically, the secondary profile is either **mix** or **qpsk**.

Note The **cable modulation-profile** command also supports setting the individual parameters for the initial, long grant, request/data, request, short grant, and station ranging bursts. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. Cisco recommends using the **mix**, **qam-16**, and **qpsk** default modulation profiles for most cable plants.

Step 4	`Router(config)# interface` *type slot/port*	Configures the interface, where: *type* = cable *slot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)
Step 5	`Router(config-int)# cable upstream` *port-number* **modulation-profile** *primary-profile-number secondary-profile-number*	Adds the modulation profile to the interface, where: *port-number* = port number on cable modem slot (port numbers begin with a 0) *primary-profile-number* = the primary modulation profile added to the interface. *secondary-profile-number* = the additional modulation profile added to the interface.
Step 6	`Router(config-int)# exit`	Exits back to configuration mode.

Note For more information on the **cable upstream modulation-profile** command, see the *Cisco Broadband Cable Command Reference Guide* on Cisco.com and on the Documentation CD-ROM.

For examples of how to view modulation profile information and to define a modulation profile, see the "Dynamic Upstream Modulation Examples" section on page 3-64.

Setting Input Power Level

When you set the frequency, you may also set the input power level. To set upstream input power levels, use one of the following commands in global configuration mode.

Command	Purpose
`CMTS01(config)# cable spectrum-group group-number [{frequency up-freq-hz [power-level-dbmv]|band up-freq-hz up-freq2-hz [power-level-dBmV]}]` or	The *power-level-dBmV* argument sets the input power level for the frequency or band you are adding. The standard power level is 0 dBmV. The valid range is –10 to +10dBmV. The **frequency** option adds an upstream frequency to the list of valid frequencies for a spectrum group. Specifies the center frequency for the given spectrum group for a frequency hop. The **band** option adds a band to the spectrum group. The band is a range of center frequencies that the CMTS can scan in order to find an acceptable channel to which the spectrum group may hop.
`CMTS01(config)# cable spectrum-group group-number [time day hh:mm:ss] [{frequency up-freq-hz [power-level-dbmv]|band up-freq-hz up-freq2-hz [power-level-dBmV]}]`	The *power-level-dbmv option* sets an input power level for the frequency or band you are adding at a particular time. The standard power level is 0 dBmV. The valid range is –10 to +10dBmV. The **frequency** option adds an upstream frequency to the spectrum group at a particular time. The **band** option adds a band to the spectrum group. The **time** option specifies a time of day that the CMTS should automatically perform a frequency hop for the given spectrum group.

For an example of setting input power levels, see the "Input Power Level Examples" section on page 3-66.

Verifying Frequency Hopping

You can verify frequency hopping on the CMTS either by using command-line interface (CLI) commands or by using an RF tone generator.

Verifying Frequency Hopping Using CLI Commands

To verify frequency hopping using CLI commands, use the following procedure:

Step 1 Verify that the interface being tested is up, using the **show interface cable** command in privileged EXEC mode. The first line of the output should show that both the interface and line protocol are up. (The following examples assume that the cable interface is in slot 6.)

```
CMTS01# show interface c6/0
Cable6/0 is up, line protocol is up
  Hardware is BCM3210 ASIC, address is 000a.13e8.1ca8 (bia 000a.13e8.1ca8)
  Internet address is 10.20.114.33/27
  MTU 1500 bytes, BW 27000 Kbit, DLY 1000 usec,
...
```

Step 2 Verify that the upstream being tested is up, using the **show interface cable upstream** command. The first line shows that the upstream is up. (This example assumes that upstream 5 is being tested.)

```
CMTS01# show interface c6/0 upstream 5
Cable6/0: Upstream 5 is up
     Received 8 broadcasts, 0 multicasts, 6388105 unicasts
     0 discards, 0 errors, 0 unknown protocol
     6388113 packets input, 0 uncorrectable
     0 noise, 0 microreflections
     Total Modems On This Upstream Channel : 23 (22 active)
CMTS01#
```

Step 3 Use the **show cable hop upstream** command to display the frequency that the upstream is currently using:

```
CMTS01# show cable hop c6/0 upstream 5
Upstream    Port       Poll Missed Min    Missed Hop   Hop     Corr    Uncorr
Port        Status     Rate Poll   Poll   Poll   Thres Period  FEC     FEC
                       (ms) Count  Sample Pcnt   Pcnt  (sec)   Errors  Errors
Cable6/0/U5 16.816 Mhz 1000 0      10         0%   20%  25     0       0
```

Step 4 Use the **test cable hop** command to force the desired upstream to perform a frequency hop. A few seconds after giving the command, a console message should appear informing you of the hop. Repeat the command as needed to verify that all of the frequencies shown are within the spectrum group that has been assigned to the upstream.

```
CMTS01# test cable hop c6/0 upstream 5

2w0d: %UBR7200-5-USFREQCHG: Interface Cable6/0 Port U5, frequency changed to 15.760 MHz

CMTS01# test cable hop c6/0 upstream 5

2w0d: %UBR7200-5-USFREQCHG: Interface Cable6/0 Port U5, frequency changed to 26.832 MHz
```

Verifying Frequency Hopping Using an RF Tone Generator

To verify frequency hopping using an RF tone generator, first verify that the upstream is performing properly. Then inject a tone to the upstream port at the current upstream frequency and cable modem power level.

For example, if the upstream frequency is 22.4-MHz, inject a 22.4 MHz tone at approximately the same power level as the modem. If the power level at the modem is 40 dBmV, set the tone power to 40 dBmV. The interfering carrier should shut down the channel and cause the frequency to change to the next configured value (such as 24.0 MHz).

If you do not have an RF tone generator, use another line card and modem that carries traffic. Connect the upstream to the same combiner group, and use the data carrier as an interfering signal by setting it to the same frequency. For example, to test frequency hopping on c3/0, install c4/0 and connect both upstreams together using a combiner. If the upstream frequency of c3/0 is 22.4 MHz, set c4/0 to 22.4 MHz while c4/0 is carrying traffic. This should force c3/0 to change the frequency to the next configured value.

The comparison of the number of errors versus the number of error-free packets is a measure of the link quality. The percentage of errors should be less than 1 percent.

Troubleshooting Spectrum Group Characteristics

To troubleshoot the configuration, make sure that you entered a valid spectrum group number, time, frequency, and input power level. Also, when defining your spectrum, use the following guidelines:

- Avoid frequencies with known ingress problems, such as amateur radio bands or short-wave bands.
- Avoid hostile spectrum below 20 MHz.
- Allow extra bands for frequency hopping.
- Place upstream ports in the same combiner group in a shared spectrum group.
- Use the receive power level setting to perform slight equalization adjustments.

Advanced Spectrum Management Configuration Tasks (Cisco uBR7200 Series)

The following sections describe the configuration tasks that are needed to configure the Cisco uBR7200 series router for the Intelligent and Advanced spectrum management features that are available when using the Cisco uBR-MC16S cable interface line card.

- "Configuring Spectrum Groups" section on page 3-37
- "Configuring Dynamic Upstream Modulation" section on page 3-39
- "Configuring Proactive Channel Management" section on page 3-40
- "Verifying the Spectrum Management Configuration" section on page 3-41

Note Do not use the commands in this section to configure the Cisco uBR10012 router with the Cisco uBR-LCP2-MC16S cable interface line card. Instead, use the instructions given in the "Advanced Spectrum Management Configuration Tasks (Cisco uBR10012)" section on page 3-44.

Configuring Spectrum Groups

Frequency hopping cannot be done without first creating one or more spectrum groups, which define the specific frequencies that are available to an upstream. A spectrum group can contain a range of frequencies as well as a list of specific frequencies. This allows efficient frequency hopping, so that upstreams can avoid frequencies that have known interference and other ingress noise problems.

To configure a spectrum group with a range of frequencies, use the following procedure:

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# cable spectrum-group` *group-number* [*day* **time** *hh:mm:ss*] **band** *up-freq-hz up-freq2-hz* [*power-level-dbmv*]	Creates a spectrum group and specifies a range of frequencies that belong to the group. *group-number* = Spectrum group number. Valid range is 1 to 32. Configuring a spectrum group with multiple entries of this type, defines a list of frequencies that are available for use as upstream frequencies. *day* and **time** *hh:mm:ss* = (Optional) For scheduled spectrum groups, specifies the day of the week (**Sun**–**Sat**) and the time of day that the frequency and input power level should change. **band** *up-freq-hz up-freq2-hz* = Sets the band of frequencies for this spectrum group. The valid range for *up-freq-hz* and *up-freq2-hz is* 5,000,000 to 42,000,000 Hz, but *up-freq2-hz* must be greater than *up-freq-hz*. *power-level-dbmv* = (Optional) Nominal input power level. Valid range is –10 to +10 decibels per millivolt (dBmV), with a default of 0 dBmV. Some cable plants might want to change only the input power level and not frequency on a daily time schedule.
	Note When configuring a band of frequencies, specify a band that is 500 KHz larger than the largest desired channel width, to ensure that the largest channel width can still be used when changing the center frequency within the band.	
Step 3	`Router(config)# cable spectrum-group` *group-number* **hop period** *seconds*	Specifies the minimum time in seconds between frequency hops for the spectrum group. The default value is 25 seconds.
Step 4	`Router(config)# interface` *type slot/port*	Configures the interface where: *type* = cable *lot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)
Step 5	`Router(config-if)# cable` *n* **spectrum-group** *y*	Enters interface configuration mode, and assigns the upstream port to the frequency hop table for the associated spectrum group.
Step 6	`Router(config-if)# cable upstream` *port* **spectrum group** *y*	Assigns upstream ports individually. Valid only for Cisco uBR-MC16S card.
Step 7	`Router(config-if)# exit`	Exits configuration mode and force the system to hop.

To configure a spectrum group with multiple fixed frequencies, use the following procedure:

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# cable spectrum-group group-number [day time hh:mm:ss] frequency up-freq-hz [power-level-dbmv]`	Creates a spectrum group and specifies the frequency (or frequencies) that belong to the group. *group-number* = Spectrum group number. Valid range is 1 to 32. Configuring a spectrum group with multiple entries of this type, defines a list of frequencies that are available for use as upstream frequencies. *day* and **time** *hh:mm:ss* = (Optional) For scheduled spectrum groups, specifies the day of the week (Sun–Sat) and the time of day that the frequency and input power level should change. **frequency** *up-freq-hz* = Specific upstream frequency. Valid range is 5,000,000 to 42,000,000 Hz. *power-level-dbmv* = (Optional) Nominal input power level. Valid range is –10 to +10 decibels per millivolt (dBmV). Some cable plants might want to change only the input power level and not frequency on a daily time schedule.
Step 3	`Router(config)# cable spectrum-group group-number [time hh:mm:ss] frequency up-freq-hz [power-level-dbmv]`	Repeat this command to assign multiple specific frequencies to one spectrum group. **Note** You must assign a minimum of two frequencies to a spectrum group to enable frequency hopping. If only one frequency is assigned to a spectrum group, no hopping occurs, unless guided hopping has been enabled with the **cable upstream hopping blind** command.
Step 4	`Router(config)# cable spectrum-group group-number hop period seconds`	Specifies the minimum time in seconds between frequency hops for the spectrum group. The default value is 25 seconds.
Step 5	`Router(config)# interface type slot/port`	Configures the interface where: *type* = cable *slot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)

Step 6	`Router(config-if)# cable upstream n spectrum-group y`
	or
	`Router(config-if)# cable spectrum-group y`
		Assigns the spectrum group *y* to the upstream port *n* on the Cisco uBR-MC16S cable interface line card.
		Assigns the spectrum group *y* to all upstream ports on the cable interface card.

Step 7	`Router(config-if)# exit`	Exits configuration mode and forces the system to hop.

Configuring Dynamic Upstream Modulation

To enable the Dynamic Upstream Modulation feature for the Cisco uBR-MC16S cable interface line card, create at least two modulation profiles then assign them to the appropriate upstream.

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# cable modulation-profile` *profile* `[ mix | qam-16 | qpsk ]`	Creates a modulation profile. A modulation profile is a collection of six burst profiles sent out in a UCD message to configure modem transmit parameters for the upstream message types: request, reqdata, initial maintenance, station maintenance, short grant, and long grant. *profile* = Modulation profile number (1–8). **mix** = Creates a default QPSK/QAM-16 mix modulation profile (short and long grant bursts are sent using QAM-16, while request, initial ranging, and station maintenance bursts are sent using QPSK). **qam-16** = Creates a default QAM-16 modulation profile, where all bursts are sent using QAM-16. **qpsk** = Creates a default QPSK modulation profile, where all bursts are sent using QPSK. **Note** Do not use the QAM-16 mode unless you have verified that your cable plant can support that modulation profile. Most cable plants should instead use the **mix** modulation profile for the primary profile.
Step 3	`Router(config)# cable modulation-profile` *profile* `[ mix | qam-16 | qpsk ]`	Repeat this command to create the secondary profile. Typically, the secondary profile is either **mix** or **qpsk**.

Note The **cable modulation-profile** command also supports setting the individual parameters for the initial, long grant, request/data, request, short grant, and station ranging bursts. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. Cisco recommends using the **mix**, **qam-16**, and **qpsk** default modulation profiles for most cable plants.

Step 4	`Router(config)# interface` *type slot/port*	Enters interface configuration mode for the cable interface where: *type* = **cable** *slot* = slot number in chassis for the Cisco uBR-MC16S line card (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)

	Command	Purpose
Step 5	`Router(config-if)# cable upstream` *n* `modulation-profile` *primary-profile-number secondary-profile-number*	Adds the modulation profile to an upstream on the cable interface. *n* = upstream number on cable modem slot (on the Cisco uBR-MC16S, upstream port numbers are 0–5) *primary-profile-number* = the primary modulation profile added to the interface. *secondary-profile-number* = the secondary modulation profile added to the interface.
Step 6	`Router(config-if)# cable upstream` *n* `modulation-profile` *primary-profile-number secondary-profile-number*	Repeat this command up to five times to configure the six upstreams on the Cisco uBR-MC16S line card.
Step 7	`Router(config-if)# exit`	Exits back to the configuration mode.

Configuring Proactive Channel Management

To optimize the spectrum management behavior for your plant's specific characteristics, you can customize the following parameters:

- Optionally specify the priority of the corrective actions to be taken when noise on an upstream exceeds the threshold for its modulation profile.
- Optionally configure the CNR threshold and FEC values for the upstream and its two modulation profiles.
- Optionally specify the allowable range of channel widths that can be used if frequency hopping or modulation switching cannot avoid the upstream problems.

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# interface` *type slot/port*	Configures the interface where: *type* = cable *slot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)

Step 3	`Router(config-if)# cable upstream` *n* `hop-priority frequency modulation channel-width`
	or
	`Router(config)# cable upstream` *n* `hop-priority modulation frequency channel-width`
	or
	`Router(config)# cable upstream` *n* `hop-priority frequency channel-width modulation`
		(Optional) Specifies the priority of the three types of corrective actions to be taken.
		n = upstream number on cable modem slot (on the Cisco uBR-MC16S, upstream port numbers are 0–5)
		The three parameters (**modulation**, **frequency**, and **channel-width**) specify the order of the corrective actions to be taken when the noise for the upstream exceeds the threshold specified for the current modulation profile. When setting the allowable parameters, the **channel-width** option must always appear after the **frequency** option.

	Command	Purpose
Step 4	`Router(config-if)# cable upstream` *n* `threshold cnr-profile1` *threshold1-in-dB* `cnr-profile2` *threshold2-in-dB* `corr-fec` *fec-corrected* `uncorr-fec` *fec-uncorrected*	(Optional) Specifies the CNR threshold and FEC values for the upstream and its two modulation profiles. *n* = upstream number on cable modem slot (on the Cisco uBR-MC16S, upstream port numbers are 0–5) **cnr-profile1** *threshold1-in-dB* = CNR threshold for the primary modulation profile (5-35 dB, with a default of 25) **cnr-profile2** *threshold1-in-dB* = CNR threshold for the secondary modulation profile (5-35 dB, must be less than that for the primary modulation profile, with a default of 15) **corr-fec** *fec-corrected* = FEC corrected threshold as a percentage of total packets on the upstream (3-50%, with a default of 3%) **uncorr-fec** *fec-uncorrected* = FEC uncorrected threshold as a percentage of total packets on the upstream (1–10%, with a default of 1%)
Step 5	`Router(config-if)# cable upstream` *n* `channel-width` *width1 width2*	(Optional) Specifies the range of channel widths to scan when ingress noise conditions require changing the channel width. **channel-width** *width1 width2* = the range of channel widths. Valid values are 200000 Hz (160 kilosymbols per second [ksps]), 400000 Hz (320 ksps), 800000 Hz (640 ksps), 1600000 Hz (1280 ksps), and 3200000 Hz (2560 ksps), where *width1* specifies the default upstream channel width, and *width2* specifies the last allowable (minimum) channel width; *width2* must be smaller than *width1*. **Note** The channel width starts at the primary channel and decreases in half until it hits the secondary channel width. For example, **cable upstream** *0* **channel-width** *3200000 400000* means that channel width starts with a 3.2 MHz wide channel, then moves to 1.6 MHz, then .8 MHz, then .4 MHz. The default is a single channel width of 1600000 Hz.
Step 6	`Router(config-if)# exit`	Exits back to the configuration mode.

Verifying the Spectrum Management Configuration

Step 1 To check the value of the settings you have entered, enter the **show running-config** command in privileged EXEC mode at the `Router#` prompt:

```
Router# show running-config
```

To review changes you make to the configuration, use the **show startup-config** command in privileged EXEC mode to display the information stored in NVRAM.

Step 2 To display modulation profile group information, use the **show cable modulation-profile** command in privileged EXEC mode:

```
Router# show cable modulation-profile [profile] [iuc-code]
```

profile—(Optional) Profile number (1–8).

iuc-code—(Optional) Internal usage code (IUC). Valid options are:

- **initial**—Initial ranging burst
- **long**—Long grant burst
- **request**—Request burst
- **reqdata**—Request data burst
- **short**—Short grant burst
- **station**—Station ranging burst

Step 3 To display the status and configuration of each upstream, use the **show controllers cable upstream** command in privileged EXEC mode. The following example shows the display for the first two upstreams on a Cisco uBR-MC16S line card:

```
CMTS# show controllers c6/0 upstream
 Cable6/0 Upstream 0 is administratively down
  Frequency not set, Channel Width 1.600 MHz, QPSK Symbol Rate 1.280 Msps
  Spectrum Group is unassigned
  CNR - Unknown - no modems online.
  Nominal Input Power Level 0 dBmV, Tx Timing Offset 0
  Ranging Backoff automatic (Start 0, End 3)
  Ranging Insertion Interval automatic (60 ms)
  Tx Backoff Start 0, Tx Backoff End 4
  Modulation Profile Group 1
  Concatenation is enabled
  Fragmentation is enabled
  part_id=0x3137, rev_id=0x03, rev2_id=0xFF
  nb_agc_thr=0x0000, nb_agc_nom=0x0000
  Range Load Reg Size=0x58
  Request Load Reg Size=0x0E
  Minislot Size in number of Timebase Ticks is = 8
  Minislot Size in Symbols = 64
  Bandwidth Requests = 0x0
  Piggyback Requests = 0x0
  Invalid BW Requests= 0x0
  Minislots Requested= 0x0
  Minislots Granted  = 0x0
  Minislot Size in Bytes = 16
  Map Advance (Dynamic) : 2180 usecs
  UCD Count = 0
  DES Ctrl Reg#0 = C000C043, Reg#1 = 0
 Cable6/0 Upstream 1 is up
   Frequency 25.008 MHz, Channel Width 1.600 MHz, 16-QAM Symbol Rate 1.280 Msps
   Spectrum Group 1, Last Frequency Hop Data Error: NO(0)
   MC16S CNR measurement - 45 dB
   Nominal Input Power Level 0 dBmV, Tx Timing Offset 2811
   Ranging Backoff automatic (Start 0, End 3)
   Ranging Insertion Interval automatic (60 ms)
   Tx Backoff Start 0, Tx Backoff End 4
   Modulation Profile Group 1
   Concatenation is enabled
   Fragmentation is enabled
   part_id=0x3137, rev_id=0x03, rev2_id=0xFF
   nb_agc_thr=0x0000, nb_agc_nom=0x0000
```

```
   Range Load Reg Size=0x58
   Request Load Reg Size=0x0E
   Minislot Size in number of Timebase Ticks is = 8
   Minislot Size in Symbols = 64
   Bandwidth Requests = 0x12
   Piggyback Requests = 0x5
   Invalid BW Requests= 0x0
   Minislots Requested= 0xFA
   Minislots Granted  = 0xFA
   Minislot Size in Bytes = 32
   Map Advance (Dynamic) : 2454 usecs
   UCD Count = 230
   DES Ctrl Reg#0 = C000C043, Reg#1 = 0
   Dynamic Services Stats:
   DSA: 0  REQs  0 RSPs  0 ACKs
   0 Successful DSAs  0 DSA Failures
   DSC: 0  REQs  0 RSPs  0 ACKs
   0 Successful DSCs  0 DSC Failures
   DSD:  0 REQs  0 RSPs
   0 Successful DSDs  0 DSD Failures

   DCC: 0  REQs  0 RSPs  0 ACKs
   0 Successful DCCs  0 DCC Failures
CMTS#
```

Note In the above example, upstream 0 displays “CNR - Unknown - no modems online” to indicate that the CNR value has not yet been calculated because no cable modems have come online for that particular upstream yet.

Step 4 To display the hop period and hop threshold values for each upstream, use the **show cable hop** in privileged EXEC mode command:

```
CMTS# show cable hop
 Upstream    Port       Poll Missed Min    Missed Hop   Hop     Corr    Uncorr
 Port        Status     Rate Poll   Poll   Poll   Thres Period  FEC     FEC
                        (ms) Count  Sample Pcnt   Pcnt  (sec)   Errors  Errors
Cable3/0/U0 20.800 Mhz 105  0      20         0%   25%  45     1       4
Cable3/0/U1 20.800 Mhz 105  0      48         0%   25%  45     2       19
Cable3/0/U2 23.120 Mhz 105  0      45         0%   25%  45     0       5
Cable3/0/U3 22.832 Mhz 105  0      26         0%   25%  45     0       6
Cable3/0/U4 22.896 Mhz 105  0      43         0%   25%  45     0       7
Cable3/0/U5 23.040 Mhz 105  0      54         0%   25%  45     1       3
Cable4/0/U0 22.896 Mhz 117  0      26         0%   25%  45     0       2
Cable4/0/U1 23.168 Mhz 117  0      87         0%   25%  45     4       2
Cable4/0/U2 22.896 Mhz 117  0      23         0%   25%  45     1       0
Cable4/0/U3 20.800 Mhz 117  0      54         0%   25%  45     0       0
Cable4/0/U4 22.928 Mhz 117  0      22         0%   25%  45     0       1
Cable4/0/U5 22.960 Mhz 117  0      0       -----   25%  45     0       0
CMTS#
```

Step 5 To display the assignment of each spectrum group, use the **show cable spectrum-group** command in privileged EXEC mode:

```
CMTS# show cable spectrum-group
Group  Frequency      Upstream     Weekly Scheduled           Power   Shared
No.    Band           Port         Availability               Level   Spectrum
       (Mhz)                       From Time:    To Time:     (dBmV)

1      20.000-21.600                                         0       No
1      22.000-24.000                                         0       No
1      20.784 [1.60]  Cable3/0 U0                            0
1      20.784 [1.60]  Cable3/0 U1                            0
```

```
1      23.120 [1.60]  Cable3/0 U2                              0
1      22.832 [1.60]  Cable3/0 U3                              0
1      22.896 [1.60]  Cable3/0 U4                              0
1      23.024 [1.60]  Cable3/0 U5                              0
1      23.152 [1.60]  Cable4/0 U1                              0
1      22.896 [1.60]  Cable4/0 U0                              0
1      22.896 [1.60]  Cable4/0 U2                              0
1      20.784 [1.60]  Cable4/0 U3                              0
1      22.928 [1.60]  Cable4/0 U4                              0
1      22.960 [1.60]  Cable4/0 U5                              0
```

Step 6 To display the current CNR value for a particular cable modem, use the **show cable modem cnr** command in privileged EXEC mode:

```
CMTS# show cable modem 10.240.179.234 cnr
MAC Address    IP Address      I/F     MAC         Prim  CNR
                                       State       Sid   (db)
0020.40bc.3588 10.240.179.234  C3/0/U2 online      2     38.0

CMTS# show cable modem 10.240.179.51 cnr
MAC Address    IP Address      I/F     MAC         Prim  CNR
                                       State       Sid   (db)
0020.40ef.4be0 10.240.179.51   C3/0/U5 online      11    39.5
CMTS#
```

Advanced Spectrum Management Configuration Tasks (Cisco uBR10012)

The following sections describe the configuration tasks that are needed to configure the Cisco uBR10012 router for the Intelligent and Advanced spectrum management features that are available when using the Cisco uBR-LCP2-MC16S cable interface line card.

- "Configuring Spectrum Groups" section on page 3-44
- "Configuring Upstream Modulation" section on page 3-46
- "Configuring Proactive Channel Management" section on page 3-47
- "Verifying the Spectrum Management Configuration" section on page 3-48

Note This section describes the configuration that is needed to comply with the limitations and restrictions that are documented in the "Cisco uBR10012 Router and Cisco IOS Release 12.2(8)BC2 Support" section on page 3-19. Do not use the commands in this section to configure the Cisco uBR7200 series router with the Cisco uBR-MC16S cable interface line card. Instead, use the instructions given in the "Advanced Spectrum Management Configuration Tasks (Cisco uBR7200 Series)" section on page 3-36.

Configuring Spectrum Groups

Frequency hopping requires creating one or more spectrum groups, which define the specific frequencies that are available to an upstream. A spectrum group can contain a range of frequencies as well as a list of specific frequencies. This allows efficient frequency hopping, so that upstreams can avoid frequencies that have known interference and other ingress noise problems.

To configure a spectrum group with a range of frequencies, use the following procedure:

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# cable spectrum-group group-number [day time hh:mm:ss] band up-freq-hz up-freq2-hz [power-level-dbmv]`	Creates a spectrum group and specifies a range of frequencies that belong to the group. *group-number* = Spectrum group number. Valid range is 1 to 32. Configuring a spectrum group with multiple entries of this type, defines a list of frequencies that are available for use as upstream frequencies. *day* and **time** *hh:mm:ss* = (Optional) For scheduled spectrum groups, specifies the day of the week (**Sun**–**Sat**) and the time of day that the frequency and input power level should change. **band** *up-freq-hz up-freq2-hz* = Sets the band of frequencies for this spectrum group. The valid range for *up-freq-hz* and *up-freq2-hz is* 5,000,000 to 42,000,000 Hz, but *up-freq2-hz* must be greater than *up-freq-hz*. *power-level-dbmv* = (Optional) Nominal input power level. Valid range is –10 to +10 decibels per millivolt (dBmV), with a default of 0 dBmV. Some cable plants might want to change only the input power level and not frequency on a daily time schedule.
	Note When configuring a band of frequencies, specify a band that is 500 KHz larger than the largest desired channel width, to ensure that the largest channel width can still be used when changing the center frequency within the band.	
Step 3	`Router(config)# cable spectrum-group group-number hop period 30`	Specifies the minimum time in seconds between frequency hops for the spectrum group. The default value is 300 seconds, but it should be set to **30** for proper operation when using Cisco IOS Release 12.2(8)BC2 on the Cisco uBR10012 router and Cisco uBR-LCP2-MC16 cable interface line card.
Step 4	`Router(config)# interface cable slot/port`	Enters interface configuration mode for the cable interface where: *slot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)

Step 5	`Router(config-if)# cable upstream n spectrum-group y`
	`or`
	`Router(config-if)# cable spectrum-group y`
		Assigns the spectrum group *y* to the upstream port *n* on the Cisco uBR-MC16S cable interface line card.
		`or`
		Assigns the spectrum group *y* to all upstream ports on the cable interface card.
		Note Repeat the above commands as needed to configure each upstream port.

Step 6	`Router(config-if)# no cable upstream port shutdown`	Enables the upstream port. Repeat this command as needed to configure each upstream port.
Step 7	`Router(config-if)# exit`	Exits configuration mode and force the system to hop.

The Cisco uBR10012 router using Cisco IOS Release 12.2(8)BC2 does not support spectrum groups with fixed frequencies.

Configuring Upstream Modulation

To create and configure the module profile for the Cisco uBR-LCP2-MC16S cable interface line card on the Cisco uBR10012 router, and then to assign it to the appropriate upstreams, use the following procedure:

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# cable modulation-profile` *profile* {**qpsk** | **mix** | **qam-16**}	Creates a modulation profile using the predefined profile for QPSK modulation. *profile* = Modulation profile number (1–8). **qpsk** = Creates a default QPSK modulation profile, where all bursts are sent using QPSK. **mix** = Creates a default QPSK/16-QAM mix modulation profile where short and long grant bursts are sent using 16-QAM, while request, initial ranging, and station maintenance bursts are sent using QPSK. **qam-16** = Creates a default 16-QAM modulation profile, where all bursts are sent using 16-QAM.
	Note The **cable modulation-profile** command also supports setting the individual parameters for the initial, long grant, request/data, request, short grant, and station ranging bursts. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer.	
Step 3	`Router(config)# interface cable` *slot/port*	Enters interface configuration mode for the cable interface where: *slot* = slot number in chassis for the Cisco uBR-LCP2-MC16S line card (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)
Step 4	`Router(config-int)# cable upstream` *n* **modulation-profile** *profile* [*secondary-profile-number*]	Adds the modulation profile to an upstream on the cable interface. *n* = upstream number on cable modem slot (on the Cisco uBR-MC16S, upstream port numbers are 0–5) *profile* = the modulation profile to be assigned to the upstream. (Specify the profile number created with the **cable modulation-profile** command in Step 2 above.) *secondary-profile-number* = (Optional) Secondary modulation profile for the upstream port, which is used when noise on the upstream increases to the point that the primary modulation profile can no longer be used. **Note** The secondary modulation profile should specify a more robust performance profile (in terms of coping with noise) than the primary profile.
Step 5	`Router(config-int)# cable upstream` *n* **modulation-profile** *profile*	Repeat this command as needed to configure the six upstreams on the Cisco uBR-LCP2-MC16S line card.
Step 6	`Router(config-int)# exit`	Exits back to the configuration mode.

Configuring Proactive Channel Management

To optimize the spectrum management behavior for your plant's specific characteristics, you can customize the following parameters:

- Optionally specify the priority of the corrective actions to be taken when noise on an upstream exceeds the threshold for its modulation profile.
- Optionally configure the CNR threshold and FEC values for the upstream and its two modulation profiles.
- Optionally specify the allowable range of channel widths that can be used if frequency hopping or modulation switching cannot avoid the upstream problems.

	Command	Purpose
Step 1	`Router(config)# configure terminal`	Enters configuration mode.
Step 2	`Router(config)# interface cable slot/port`	Enters interface configuration mode for the cable interface where: *slot* = slot number in chassis (slot numbers begin with a 0) *port* = port number on cable modem slot (port numbers begin with a 0)

Step 3	`Router(config-if)# cable upstream n hop-priority frequency modulation channel-width`
	
	or
	
	`cable upstream n hop-priority modulation frequency channel-width`
	
	or
	
	`cable upstream n hop-priority frequency channel-width modulation`
		(Optional) Configures the priority of corrective actions to be taken when ingress noise occurs on a downstream.
		
		n = upstream number on cable modem slot (on the Cisco uBR-MC16S, upstream port numbers are 0 to 5).
		
		frequency, **modulation**, **channel-width** = Specifies the order of corrective actions to be taken. The default order is **frequency**, **modulation**, and **channel-width**. The **channel-width** option must come after the **frequency** option, either immediately or after the **modulation** option, as shown in the above examples.

Step 4	`Router(config-if)# cable upstream n channel-width first-choice-width [last-choice-width]`	(Optional) Specifies the range of channel widths to scan when ingress noise conditions require changing the channel width. *first-choice-width* = Specifies upstream channel width in hertz (Hz). Valid values are: 200,000 (160,000 symbols/sec), 400,000 (320,000 symbols/sec), 800,000 (640,000 symbols/sec), 1600,000 (1,280,000 symbols/sec), and 3,200,000 (2,560,000 symbols/sec). *last-choice-width* = (Optional) The upstream channel width in hertz. The valid values are the same as those for the first-choice-width parameter. Use this parameter with the Cisco uBR-MC16S cable interface line card to enable symbol rate management algorithms. The symbol rate automatically steps up from the `first-choice-width` value to the highest value until a stable channel is established.

	Command	Purpose
Step 5	`Router(config-if)# cable upstream` *n* `threshold cnr-profile1` *threshold1-in-dB* `cnr-profile2` *threshold2-in-dB* `corr-fec` *fec-corrected* `uncorr-fec` *fec-uncorrected*	(Optional) Specifies the CNR threshold and FEC values for the upstream and its two modulation profiles. *n* = upstream number on cable modem slot (on the Cisco uBR-LCP2-MC16S, upstream port numbers are 0 to 5) **cnr-profile1** *threshold1-in-dB* = CNR threshold for the primary modulation profile (5 to 35 dB, with a default of 16) **cnr-profile2** *threshold1-in-dB* = CNR threshold for the secondary modulation profile (5 to 35 dB, must be less than that for the primary modulation profile, with a default of 5) **corr-fec** *fec-corrected* = FEC corrected threshold as a number packets on the upstream (0 to 500 packets, with a default of 1) **uncorr-fec** *fec-uncorrected* = FEC uncorrected threshold as a number of packets on the upstream (0 to 500 packets, with a default of 1) **Note** Cisco recommends using the default values for all parameters in this command.
Step 6	`Router(config-if)# exit`	Exits back to the configuration mode.

Verifying the Spectrum Management Configuration

Step 1 To check the value of the settings you have entered, enter the **show running-config** command in privileged EXEC mode at the `Router#` prompt:

```
Router# show running-config
```

To review changes you make to the configuration, use the **show startup-config** command in privileged EXEC mode to display the information stored in NVRAM.

Step 2 To display modulation profile group information, use the **show cable modulation-profile** command in privileged EXEC mode:

```
Router# show cable modulation-profile [profile] [iuc-code]
```

profile—(Optional) Profile number (1–8).

iuc-code—(Optional) Internal usage code (IUC). Valid options are:

- **initial**—Initial ranging burst
- **long**—Long grant burst
- **request**—Request burst
- **reqdata**—Request data burst
- **short**—Short grant burst
- **station**—Station ranging burst

Step 3 To display the status and configuration of each upstream, use the **show controllers cable upstream** command in privileged EXEC mode. The following example shows the display for an upstream on a Cisco uBR-LCP2-MC16S line card:

```
CMTS# show controllers c6/1/0 upstream
  Cable6/1/0 Upstream 0 is up
```

```
   Frequency 15.792 MHz, Channel Width 1.600 MHz, QPSK Symbol Rate 1.280   Msps
   Spectrum Group 14, Last Frequency Hop Data Error: NO(0)
   MC16S CNR measurement - 29 dB
   Nominal Input Power Level 0 dBmV, Tx Timing Offset 2294
   Ranging Backoff automatic (Start 0, End 3)
   Ranging Insertion Interval automatic (60 ms)
   Tx Backoff Start 0, Tx Backoff End 4
   Modulation Profile Group 1
   Concatenation is enabled
   Fragmentation is enabled
   part_id=0x3137, rev_id=0x03, rev2_id=0xFF
   nb_agc_thr=0x0000, nb_agc_nom=0x0000
   Range Load Reg Size=0x58
   Request Load Reg Size=0x0E
   Minislot Size in number of Timebase Ticks is = 8
   Minislot Size in Symbols = 64
   Bandwidth Requests = 0x25034
   Piggyback Requests = 0x178D5
   Invalid BW Requests= 0x9
   Minislots Requested= 0x1F452F
   Minislots Granted  = 0x1F452F
   Minislot Size in Bytes = 16
   Map Advance (Dynamic) : 2404 usecs
   UCD Count = 49803
   DES Ctrl Reg#0 = C000C043, Reg#1 = 0

CMTS#
```

Step 4 To display the hop period and hop threshold values for each upstream, use the **show cable hop** command in privileged EXEC mode:

```
CMTS# show cable hop
 Upstream    Port       Poll Missed Min    Missed Hop   Hop     Corr    Uncorr
 Port        Status     Rate Poll   Poll   Poll   Thres Period  FEC     FEC
                        (ms) Count  Sample Pcnt   Pcnt  (sec)   Errors  Errors
Cable3/0/U0 20.800 Mhz 105  0      20         0%   25%  45     1       4
Cable3/0/U1 20.800 Mhz 105  0      48         0%   25%  45     2       19
Cable3/0/U2 23.120 Mhz 105  0      45         0%   25%  45     0       5
Cable3/0/U3 22.832 Mhz 105  0      26         0%   25%  45     0       6
Cable3/0/U4 22.896 Mhz 105  0      43         0%   25%  45     0       7
Cable3/0/U5 23.040 Mhz 105  0      54         0%   25%  45     1       3
Cable4/0/U0 22.896 Mhz 117  0      26         0%   25%  45     0       2
Cable4/0/U1 23.168 Mhz 117  0      87         0%   25%  45     4       2
Cable4/0/U2 22.896 Mhz 117  0      23         0%   25%  45     1       0
Cable4/0/U3 20.800 Mhz 117  0      54         0%   25%  45     0       0
Cable4/0/U4 22.928 Mhz 117  0      22         0%   25%  45     0       1
Cable4/0/U5 22.960 Mhz 117  0      0       -----   25%  45     0       0
CMTS#
```

Step 5 To display the assignment of each spectrum group, use the **show cable spectrum-group** command in privileged EXEC mode:

```
CMTS# show cable spectrum-group
Group  Frequency      Upstream     Weekly Scheduled            Power   Shared
No.    Band           Port         Availability                Level  Spectrum
       (Mhz)                        From Time:    To Time:     (dBmV)

1       6.000-11.000                                           0       No
2      12.000-17.000                                           0       No
3      18.000-23.000                                           0       No
4      24.000-29.000                                           0       No
6      36.000-41.000                                           0       No
10     15.000-20.000                                           0       No
11     15.000-20.000                                           0       No
```

```
12     15.000-20.000                                          0       No
13     15.000-20.000                                          0       No
14     15.000-20.000                                          0       No
14     24.000-29.000                                          0       No
14     15.792 [1.60]  Cable6/1/0 U0                           0
15     15.000-20.000                                          0       No
16     20.000-21.600                                          0       No
17     30.000-33.000                                          0       No
17     30.000-33.200                                          0       No
19     30.000-34.000                                          0       No
19     20.000-24.000                                          0       No
19     10.000-14.000                                          0       No
20     20.000-24.000                                          0       No
22     20.000-30.000                                          0       No
22     25.936 [1.60]  Cable6/1/0 U1                           0
22     26.192 [1.60]  Cable6/1/0 U2                           0
22     26.480 [1.60]  Cable6/1/0 U3                           0
22     20.784 [1.60]  Cable6/1/0 U4                           0
22     23.984 [1.60]  Cable6/1/0 U5                           0
CMTS#
```

Step 6 To display the current CNR value for a particular cable modem, use the **show cable modem cnr** command in privileged EXEC mode:

```
CMTS# show cable modem 10.240.179.234 cnr
MAC Address    IP Address      I/F     MAC         Prim  CNR
                                       State       Sid   (db)
0020.40bc.3588 10.240.179.234  C3/0/U2 online      2     38.0
CMTS# show cable modem 10.240.179.51 cnr
MAC Address    IP Address      I/F     MAC         Prim  CNR
                                       State       Sid   (db)
0020.40ef.4be0 10.240.179.51   C3/0/U5 online      11    39.5
CMTS#
```

Monitoring Spectrum Management

You can use Cisco IOS CLI commands to monitor spectrum management activity on the Cisco CMTS. If you are using Cisco IOS Release 12.2(8)BC2 or later 12.2 BC releases, and the Cisco uBR-MC16S cable interface line card, you can also use SNMP to monitor the spectrum management activity. See the following sections for more information:

- Using CLI Commands, page 3-51
- Using SNMP, page 3-51
- Using the DOCSIS Cable Modem Test Analyzer, page 3-55

Using CLI Commands

The following commands provide information on the spectrum condition of an upstream:

Command	Purpose
`Router# show cable hop [cx/y] [upstream usport]`	Displays the hop period and hop threshold values, as well as the FEC error counters, for all upstreams in the router, all upstreams on one cable interface line card, or a single upstream.
`Router# show cable modem [ip-address | interface | mac-address] [options]`	Displays information, including SNR values, for the registered and unregistered cable modems. **Note** Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases also support a **cnr** option that displays the CNR value for a specific cable modem, if it is using an upstream on the Cisco uBR-MC16S cable interface line card.
`Router# show cable modulation-profile [num] [initial | long | reqdata | request | short | station ]`	Displays the configuration for all modulation profiles, for a particular modulation profile, or for a specific burst type for a particular modulation profile.
`Router# show cable spectrum-group [groupnum] [detail]`	Displays information about the spectrum groups that have been configured. **Note** The **detail** keyword is supported only in Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases.
`Router# show controllers cable x/y upstream n [ ip-address | mac-address ] start-freq end-freq res-freq`	Displays the upstream's status, including the current frequency, channel width, modulation rate, and spectrum groups.
`Router# show controllers cable x/y upstream n spectrum [ ip-address | mac-address ] start-freq end-freq res-freq`	(For Cisco uBR-MC16S only) Displays the noise levels for a particular cable modem or displays the background noise for an entire upstream.

Note The **show cable flap-list** command displays the CMTS router's flap list, which can provide additional information about whether cable modems on an upstream are experiencing problems, and if so, what type of problems are occurring. For more information, see Chapter 2, "Flap-List Troubleshooting for the Cisco Cable Modem Termination System".

Using SNMP

When you are using Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases and the Cisco uBR-MC16S cable interface line card, you can use SNMP to monitor the spectrum management activity. The SNMP manager can be a graphically based SNMP manager such as CiscoView or a specialized tool such as the DOCSIS Cable Modem Test Analyzer (DCMTA), available from Acterna Corporation.

Tip See the next section, "Using the DOCSIS Cable Modem Test Analyzer" section on page 3-55, for more information on the DCMTA tool.

The CISCO-CABLE-SPECTRUM-MIB has been enhanced to provide this SNMP support using the following MIB attributes:

- ccsSNRRequestTable, page 3-52
- ccsSpectrumRequestTable, page 3-52
- ccsSpectrumDataTable, page 3-53
- ccsUpSpecMgmtTable, page 3-54
- ccsHoppingNotification, page 3-55

ccsSNRRequestTable

Table 3-7 lists the attributes in the ccsSNRRequestTable, which contains the CNR measurements that are made for individual cable modems on an upstream:

Table 3-7 ccsSNRRequestTable Attributes

Attribute	Type	Description
ccsSNRRequestIndex	Integer32	Arbitrary index to uniquely identify each table entry.
ccsSNRRequestMacAddr	MacAddress	MAC address of the remote online cable modem being reported on.
ccsSNRRequestSNR	Integer32	SNR value, in dB, that has been measured. This value is 0 when the Operation State is “running.”
ccsSNRRequestOperation	CCSRequestOperation	Sets the current operation: start, pending, running, or abort.
ccsSNRRequestOperState	CCSRequestOperState	Reports on the current operation state: idle, pending, running, noError, aborted, notOnLine, invalidMac, timeOut, fftBusy, fftFailed, others.
ccsSNRRequestStartTime	TimeStamp	Contains the time when the SNR measurement operation starts.
ccsSNRRequestStoppedTime	TimeStamp	Contains the time when the SNR measurement stops.
ccsSNRRequestStatus	RowStatus	Controls the modification, creation, and deletion of table entries.

ccsSpectrumRequestTable

Table 3-8 lists the attributes for each entry in the ccsSpectrumRequestTable table, which is used to obtain the spectrum profile for a particular cable modem or to obtain the background SNR for an entire upstream:

Table 3-8 ccsSpectrumRequestTable Attributes

Attribute	Type	Description
ccsSpectrumRequestIndex	Integer32	Arbitrary index to uniquely identify each table entry.
ccsSpectrumRequestIfIndex	InterfaceIndex OrZero	Interface identifying the upstream.
ccsSpectrumRequestMacAddr	MacAddress	MAC address to specify an SNR value for a particular cable modem, or 0000.0000.0000 to indicate background noise for the entire spectrum.
ccsSpectrumRequestUpperFreq	CCSFrequency	Upper frequency for the frequency range to be monitored (5000 to 42000 KHz, with a default of 42000 KHz).
ccsSpectrumRequestLowFreq	CCSFrequency	Lower frequency (in KHz) for the frequency range to be monitored (5000 to 42000 KHz, with a default of 5000 KHz).
ccsSpectrumRequestResolution	Integer32	Requested resolution to determine how the frequency range should be sampled (12 to 37000 KHz, with a default of 60 KHz).
ccsSpectrumRequestStartTime	TimeStamp	Time when the spectrum measurement began.
ccsSpectrumRequestStoppedTime	TimeStamp	Time when the spectrum measurement finished.
ccsSpectrumRequestOperation	CCSRequestOperation	Starts a new spectrum management request or aborts the current one.
ccsSpectrumRequestOperState	CCSRequestOperState	Provides the operational state of the current spectrum management request.
ccsSpectrumRequestStatus	RowStatus	Controls the modification, creation, and deletion of table entries.

ccsSpectrumDataTable

Table 3-9 lists the attributes in each entry of the ccsSpectrumDataTable table, which contains the results for a spectrum request:

Table 3-9 ccsSpectrumDataTable Attributes

Attribute	Type	Description
ccsSpectrumDataFreq	CCSMeasured Frequency	Frequency in KHz for which this power measurement was made
ccsSpectrumDataPower	INTEGER	Measured received power for the given frequency (-50 to 50 dBmV)

Note The ccsSpectrumRequestTable and ccsSpectrumDataTable tables provide the same information as that provided by the **show controllers cable upstream spectrum** command.

ccsUpSpecMgmtTable

Table 3-10 lists the attributes in the ccsUpSpecMgmtTable table, which provides an entry describing each frequency hop:

Table 3-10 ccsUpSpecMgmtEntry Attributes

Attribute	Type	Description
ccsUpSpecMgmtHopPriority	INTEGER	Specifies the priority of frequency, modulation profile, and channel width in determining corrective action for excessive noise on the upstream (default is frequency, modulation profile, and channel width)
ccsUpSpecMgmtSnrThres1	Integer32	Specifies the upper SNR threshold for modulation profile 1 (5–35 dB, default of 25)
ccsUpSpecMgmtSnrThres2	Integer32	Specifies the upper SNR threshold for modulation profile 2 (5–35 dB, default of 15, and must be lower than that specified for ccsUpSpecMgmtSnrThres1)
ccsUpSpecMgmtFecCorrectThres1	Integer32	Specifies the FEC correctable error threshold for modulation profile 1 (1–20%)
ccsUpSpecMgmtFecCorrectThres2	Integer32	Deprecated and no longer used
ccsUpSpecMgmtFecUnCorrectThres1	Integer32	Specifies the FEC uncorrectable error threshold for modulation profile 1 (1–20%)
ccsUpSpecMgmtFecUnCorrectThres2	Integer32	Deprecated and no longer used
ccsUpSpecMgmtSnrPollPeriod	Integer32	Deprecated and no longer used
ccsUpSpecMgmtHopCondition	INTEGER	Reports the condition that triggers a frequency hop (SNR value or percentage of modems going offline)
ccsUpSpecMgmtFromCenterFreq	CCSFrequency	Provides the center frequency (in KHz) before the latest frequency hop
ccsUpSpecMgmtToCenterFreq	CCSFrequency	Provides the current center frequency (in KHz) after the latest frequency hop
ccsUpSpecMgmtFromBandWidth	CCSFrequency	Provides the channel width (in KHz) before the latest frequency hop
ccsUpSpecMgmtToBandWidth	CCSFrequency	Provides the current channel width (in KHz) after the latest frequency hop
ccsUpSpecMgmtFromModProfile	Integer32	Provides the modulation profile number before the latest frequency hop
ccsUpSpecMgmtToModProfile	Integer32	Provides the current modulation profile number after the latest frequency hop
ccsUpSpecMgmtSNR	Integer32	Provides the current SNR value (in dB) for the upstream

ccsHoppingNotification

Table 3-11 describes the attributes contained in the notification that is sent after each frequency hop:

Table 3-11 ccsHoppingNotification Attributes

Attribute	Type	Description
ccsUpSpecMgmtHopCondition	INTEGER	Reports the condition that triggers a frequency hop (SNR value or percentage of modems going offline)
ccsUpSpecMgmtFromCenterFreq	CCSFrequency	Provides the center frequency (in KHz) before the latest frequency hop
ccsUpSpecMgmtToCenterFreq	CCSFrequency	Provides the current center frequency (in KHz) after the latest frequency hop
ccsUpSpecMgmtFromBandWidth	CCSFrequency	Provides the channel width (in KHz) before the latest frequency hop
ccsUpSpecMgmtToBandWidth	CCSFrequency	Provides the current channel width (in KHz) after the latest frequency hop
ccsUpSpecMgmtFromModProfile	Integer32	Provides the modulation profile number before the latest frequency hop
ccsUpSpecMgmtToModProfile	Integer32	Provides the current modulation profile number after the latest frequency hop

Using the DOCSIS Cable Modem Test Analyzer

The DOCSIS Cable Modem Test Analyzer (DCMTA) is a software tool that provides spectrum analyzer capability on the Cisco uBR7200 series CMTS for troubleshooting problems with an individual upstream port or an individual cable modem. The DCMTA works together with the Cisco uBR-MC16S line card on a Cisco CMTS running Cisco IOS Release 12.2(8)BC2 and later 12.2 BC releases to display the return path spectral information from the line card and its related ports.

The DCMTA software uses SNMP requests to obtain the spectrum data from the CISCO-CABLE-SPECTRUM-MIB and displays this data in a graphical interface. The DCMTA software runs on a Windows PC and supports simultaneous client access to a single and multiple CMTS routers, upstreams, and cable modems. The software and its Windows PC can be located anywhere in your network that offers connectivity with the Cisco CMTS.

The DCMTA software provides the ability to perform real-time diagnosis of the return path, as well as live troubleshooting of an upstream port or individual cable modem. The software uses simple menus and interactive screens, allowing users to analyze the return path performance in real time as problems occur. The software offers multiple views of the spectrum management data, providing a flexible interface for isolating, characterizing, and diagnosing problems, so that technicians can make intelligent decisions about how to respond to problems in the return path.

Tip For more information about the DCMTA software, contact Acterna Corporation. In North America, call 1-800-638-2049 or +1-301-353-1550 (20400 Observation Drive, Germantown, MD, USA 20876-4023). For other locations, see their web site at http://www.acterna.com.

Follow these guidelines when using the DCMTA software tool:

- Configure matching SNMP community strings on the Cisco CMTS and DCMTA software tool so that the DCMTA software can obtain the spectrum management data using SNMP requests. On the Cisco CMTS, this requires the minimum following CLI commands:

```
snmp manager
snmp-server engineID local engine-id
snmp-server community community-string RW
snmp-server trap-source interface-providing-access-to-DCMTA-PC
snmp-server enable traps cable hopping
```

  Because the DCMTA software requires SNMP read-write access, Cisco also recommends setting up an access list that restricts SNMP read-write access to the IP address for the particular PC that is running the DCMTA software.

- The DCMTA software should be used for live troubleshooting of specific problems in the return path. Do not use DCMTA for ongoing monitoring because it requests a large volume of data for each SNMP request, and constant use could affect network bandwidth and the overall performance of the Cisco CMTS. For best results, the DCMTA software should be launched when needed and then exited after the return path problem has been resolved.
- Because the DCMTA software uses SNMP polling to obtain the spectrum management data, its graphical displays show a digital representation that appears more jagged than the analog swept spectrum displays that are generated by hardware spectrum analyzers.
- When monitoring individual cable modems, the DCMTA graphical displays could show the cable modem missing for several seconds, even though the cable modem is still connected and online. This can happen for two reasons:
  - The DOCSIS specification allows a CMTS to periodically miss a ranging burst from a cable modem without affecting the cable modem's connectivity. If this occurs while the DCMTA software is monitoring a particular cable modem, the graphical display could show that cable modem missing for several seconds.
  - The DMCTA software uses SNMP requests to obtain its spectrum management data. Because SNMP is based on the connectionless UDP protocol, it is possible that SNMP packets can be dropped or lost by the routers and other network devices between the Cisco CMTS and DCMTA PC. If this happens, the graphical display could show a drop in the spectrum that was described by the data that was contained in the lost packets.

  In both of these cases, the missing spectrum data should reappear quickly, within several seconds. If it does, and if no further problems occur with that particular cable modem or spectrum, then the problem is likely due to the transient network problems described above.

Configuration Examples

Upstream Traffic Shaping and Rate Limiting Examples

Verifying Upstream Rate Limiting Example

To determine if upstream rate limiting is configured and activated, enter the **show running-config** command and look for the cable interface configuration information. If upstream rate limiting is configured and enabled, a rate limiting entry displays in the **show running-config** command output. If upstream rate limiting is disabled, `no cable upstream rate-limit` appears in the output.

You can also perform the following tasks to verify that rate limiting is enabled on the upstream channel:

Step 1 Configure a low-peak upstream rate limit for the cable modem in its QoS profile. Either use the command-line interface (CLI) to modify the modem's QoS profile, or edit the modem's TFTP configuration file.

Use a regular rate-limiting algorithm on the upstream without rate shaping and note the drops of the excess bandwidth requests from this cable modem when it exceeds its peak upstream rate.

Use the **show interface c***x/y* **sid counters** command to see the bandwidth request drops. Verify that the upstream rate received by that modem is less than its configured peak rate due to the timeouts and backoffs produced by the drop in bandwidth requests. Enter the **show interface c***x/y* **sid** command to see the input rate at CMTS in bps.

Step 2 Enable grant shaping on the upstream channel by using the new **shaping** keyword extension to the token-bucket algorithm CLI command.

Step 3 Make the cable modem exceed its peak upstream rate by generating upstream traffic, and note the effect of grant buffering (shaping) at the CMTS. If you use cable modem-to-CMTS pings, you see a perceivable slowing down of the pings.

Let the pings run for a period to let averages at the CMTS settle; then view the upstream rate received by this single modem. Use the **show interface c***x/y* command and see the input rate in bps. This value should be close to the modem's peak upstream rate. Also note the drop counts for the modem's SID by using the **show interface sid counters** command, and verify that the CMTS no longer drops the bandwidth requests from the cable modem.

The bandwidth request drop count (from previous nonshaping test) remains unchanged when upstream rate shaping is used, indicating that the CMTS is actually shaping (buffering) the grants for the modem. Verify that the input rate at the CMTS (from the single rate-exceeded CM) stabilizes close to the configured peak rate of 128 Kbps.

Perform these steps if you are having difficulty with verification:

- Ensure that the cable connections are not loose or disconnected.
- Ensure that the cable interface line card is firmly seated in its chassis slot.
- Ensure that the captive installation screws are tight.
- Verify that you have entered the correct slot and port numbers.
- Verify that you selected a valid frequency for your router.

Configuring the Low-Peak-Rate Limit Example

```
Router# show cable modem
Interface    SID   Online     Timing Receive QoS IP address      MAC address
                   State      Offset Power
Cable3/0/U0  1     online     3564    0.00   6   1.11.53.102     0010.7b6b.7235

Router# show cable qos profile 6
Service Prio Max       Guarantee Max        Max tx TOS  TOS   Create     B
class        upstream  upstream  downstream burst  mask value by         priv
             bandwidth bandwidth bandwidth                              enab
6       7    128000    100000    4000000    0      0x0  0x0   management yes
```

Applying the Rate-Limiting Algorithm Without Rate Limiting Example

```
Router(config-if)# cable upstream 0 rate-limit

Router# ping ip
Target IP address:1.11.53.100
Repeat count [5]:100000
Datagram size [100]:10000
Timeout in seconds [2]:
Extended commands [n]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 100000, 10000-byte ICMP Echos to 1.11.53.100, timeout is 2 seconds:
!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!
.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!
!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!
.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!
.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.
!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!!.!!.!.!!
!.!!.!.!!!.!!.!.!!!.!!.!.!!!
```

```
Router# show interface c3/0 sid 1 counters
Sid   Inpackets  Inoctets   Outpackets Outoctets  Ratelimit  Ratelimit
                                                  BWReqDrop  DSPktDrop
1     67859      99158800   67570      98734862   2579       0
```

```
Router# sh int c3/0
Cable3/0 is up, line protocol is up
  Hardware is BCM3210 ASIC, address is 0009.4553.0061 (bia 0009.4553.0061)
  Internet address is 1.11.53.100/27
  MTU 1500 bytes, BW 27000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation MCNS, loopback not set, keepalive not set
  ARP type:ARPA, ARP Timeout 04:00:00
  Last input 00:00:00, output 00:00:00, output hang never
  Last clearing of "show interface" counters never
  Queueing strategy:fifo
  Output queue 0/40, 0 drops; input queue 0/75, 0 drops
  5 minute input rate 95000 bits/sec, 9 packets/sec

  5 minute output rate 82000 bits/sec, 7 packets/sec
     70093 packets input, 100855618 bytes, 4569 no buffer
     Received 992 broadcasts, 0 runts, 0 giants, 0 throttles
     3 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     68477 packets output, 100193806 bytes, 0 underruns
     0 output errors, 0 collisions, 1 interface resets
     0 output buffer failures, 0 output buffers swapped out
```

Enabling Shaping Example

```
Router(config-if)# cab u0 rate-limit token-bucket shaping
```

Forcing the Cable Modem to Exceed the Peak Rate Example

```
Router# ping ip
Target IP address:1.11.53.100
Repeat count [5]:1000000
Datagram size [100]:10000
Timeout in seconds [2]:
Extended commands [n]:
Sweep range of sizes [n]:
```

```
Type escape sequence to abort.
Sending 1000000, 10000-byte ICMP Echos to 1.11.53.100, timeout is 2
seconds:
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

Router# sh int c3/0
Cable3/0 is up, line protocol is up
  Hardware is BCM3210 ASIC, address is 0009.4553.0061 (bia 0009.4553.0061)
  Internet address is 1.11.53.100/27
  MTU 1500 bytes, BW 27000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation MCNS, loopback not set, keepalive not set
  ARP type:ARPA, ARP Timeout 04:00:00
  Last input 00:00:00, output 00:00:00, output hang never
  Last clearing of "show interface" counters 00:07:45
  Queueing strategy:fifo
  Output queue 0/40, 0 drops; input queue 0/75, 0 drops
  5 minute input rate 128000 bits/sec, 11 packets/sec

  5 minute output rate 131000 bits/sec, 11 packets/sec
     4098 packets input, 5860349 bytes, 0 no buffer
     Received 92 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     4004 packets output, 5868720 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 output buffer failures, 0 output buffers swapped out

Router# show int c3/0 sid counters
Sid   Inpackets  Inoctets   Outpackets Outoctets  Ratelimit  Ratelimit
                                                  BWReqDrop  DSPktDrop
1     4780       6996880    4774       6987772    6244       0


Router# show int c3/0 sid counters
Sid   Inpackets  Inoctets   Outpackets Outoctets  Ratelimit  Ratelimit
                                                  BWReqDrop  DSPktDrop
1     4866       7122488    4865       7120970    6244       0
```

Downstream Traffic Shaping and Rate Limiting Examples

Downstream Rate Limiting Example

The following example shows how to apply the token-bucket filter algorithm:

```
router(config-if)# cable 6/0 cable downstream rate-limit token-b
```

Verifying Downstream Rate Limiting Example

To determine if downstream rate limiting is configured and activated, enter the **show running-config** command and look for the cable interface configuration information. If downstream rate limiting is configured and enabled, a rate limiting entry appears in the output. If downstream rate limiting is disabled, no rate limiting entry appears.

```
CMTS01# show running-config
Building configuration...
Current configuration:
!
interface cable5/0/0
ip address 10.254.254.254 255.0.0.0
no ip directed-broadcast
cable helper-address 192.168.1.1
no keepalive
cable downstream rate-limit token-bucket shaping
cable downstream annex B
cable downstream modulation 64qam
```

Perform these steps if you are having difficulty with verification:

- Ensure that the cable connections are not loose or disconnected.
- Ensure that the cable interface line card is firmly seated in its chassis slot.
- Ensure that the captive installation screws are tight.
- Verify that you have entered the correct slot and port numbers
- Verify that you selected the default if you are not certain about the modulation rate needed.
- Verify the downstream carrier is active using the **cable downstream if-output** command.

Spectrum Group and Combiner Group Examples

Verifying Spectrum Group Creation Example

To verify that a spectrum group has been created, enter the **show cable spectrum-group** command:

```
CMTS01# show cable spectrum-group
spectrum-group 1
spectrum-group 2
spectrum-group 3
```

Time-Scheduled Spectrum Group Example

If your cable plant has an upstream noise characteristic on a weekly cycle, use time-scheduled spectrum allocation. An example follows:

```
CMTS01(config)# cable spectrum-group 1 time Mon 08:00:00 frequency 21600000
```

Deletion is performed using the **delete** keyword:

```
CMTS01(config)# cable spectrum-group 1 time Mon 18:00:00 delete frequency 21600000
```

Verifying Spectrum Group Configuration Example

To verify if spectrum groups have been configured and activated, enter the **show cable spectrum-group** command. This command displays each spectrum group, the frequencies assigned to it, the upstream port to which it has been assigned, whether a schedule exists for it, the currently measured power level, and whether it is a shared spectrum group.

```
CMTS01# show cable spectrum-group
22:07:46: %SYS-5-CONFIG_I: Configured from console by console
Group  Frequency      Upstream     Weekly Scheduled            Power   Shared
No.    Band           Port         Availability                Level   Spectrum
       (Mhz)                       From Time:    To Time:      (dBmV)
1       5.000-15.000                                           0       Yes
1      12.000                                                  0       Yes
1      22.000         Cable6/0 U5                             7       Yes
2      29.000         Cable6/0 U4                             6       No
2      26.000                                                 0       No
3      35.000-41.000                                          0       No
3      16.000-19.000  Cable6/0 U3                             5       No
5*      5.000-10.000               Thu 21:50:00  Thu 21:45:00  0       Yes
CMTS01#
```

Determining the Upstream Ports Assigned to a Combiner Group Example

Following is a sample topology for a CMTS with combiner groups designated A through J. Combiner groups C and E have multiple upstream ports that should be configured in a shared spectrum group. The other upstreams should be configured in a nonshared spectrum group.

In this example, ten combiner groups are served with frequency hop tables from three spectrum groups:

```
Cable3/0
DS +-----+ Upconverter +----- laser group 1
U0 +----- combiner group A
U1 +----- combiner group B
U2 +------combiner group C
U3 +------combiner group C
U4 +----- combiner group D
U5 +------combiner group E

Cable4/0
DS +-----+ Upconverter +----- laser group 2
U0 +------combiner group E
U1 +----- combiner group F
U2 +----- combiner group G
U3 +----- combiner group H
U4 +----- combiner group I
U5 +----- combiner group J
```

The laser group term refers to the set of fiber nodes that share the same downstream signal. An optical splitter is often used to create individual feeds per node.

In the downstream direction, two 6-MHz channel slots are assigned. All fiber nodes in combiner groups A through E should have a channel slot containing the downstream signal from Cable3/0. Combiner groups A through E are said to belong to laser group 1.

All fiber nodes in combiner groups E through J should have a channel slot containing the downstream signal from Cable4/0. Combiner groups E through J are said to belong to laser group 2.

Because combiner group E belongs to two laser groups, there should be two different downstream channel slots for Cable3/0 and Cable4/0.

Combiner Group Example

The following example enables spectrum management for all upstream ports, where all combiner groups use the frequency band from 20 to 26 MHz:

```
CMTS01(config)# cable spectrum-group 1 band 20000000 26000000
CMTS01(config)# cable spectrum-group 2 shared
CMTS01(config)# cable spectrum-group 2 band 20000000 26000000
CMTS01(config)# cable spectrum-group 3 shared
CMTS01(config)# cable spectrum-group 3 band 20000000 26000000
CMTS01(config)# interface Cable3/0
CMTS01(config-if)# cable spectrum-group 1
CMTS01(config-if)# cable upstream 2 spectrum-group 2
CMTS01(config-if)# cable upstream 3 spectrum-group 2
CMTS01(config-if)# cable upstream 5 spectrum-group 3
CMTS01(config-if)# exit
CMTS01(config)# interface Cable4/0
CMTS01(config-if)# cable spectrum-group 1
CMTS01(config-if)# cable upstream 0 spectrum-group 3
```

A description of the spectrum groups 1 through 3 follows:

- Spectrum group 1—This group is nonshared. Upstream RF domains exist for each member upstream port.

```
Upstream Port   RF Domain
Cable3/0 U0     combiner group A
Cable3/0 U1     combiner group B
Cable3/0 U4     combiner group D
Cable4/0 U1     combiner group F
Cable4/0 U2     combiner group G
Cable4/0 U3     combiner group H
Cable4/0 U4     combiner group I
Cable4/0 U5     combiner group J
```

- Spectrum group 2—This group is shared. A single upstream RF domain exists.

```
Upstream Port   RF Domain
Cable3/0 U2     combiner group C
Cable3/0 U3     combiner group C
```

- Spectrum group 3—This group is shared. A single upstream RF domain exists.

```
Upstream Port   RF Domain
Cable3/0 U5     combiner group E
Cable4/0 U0     combiner group E
```

For the 20- to 26-MHz band of each RF domain, the spectrum is channelized according to the channel width settings of each member port. For example, if the ports U2 and U3 of Cable3/0 are set to 3.2 MHz and 1.6 MHz channel widths, respectively, then spectrum group 2 uses the following channelization:

```
> Channel Width Start Stop Center
>           (Mhz) (Mhz) (Mhz) (Mhz)
> 1        3.2    20.0 23.2 21.6
> 2*       1.6    20.0 21.6 20.8
> 3*       1.6    21.6 23.2 22.4
> 4        1.6    23.2 24.8 24.0
```

Note Channels 2 and 3 are not available when channel 1 is in use.

Because the group is shared, ports U2 and U3 will be assigned channels 1 and 4, respectively, to prevent overlap.

Note There are no alternate frequency assignments for either port, and bandwidth is wasted from 24.8 to 26.0 MHz. To create alternate channels, increase the upper boundary from 26.0 to 28.0 MHz.

```
> Channel  Width  Start Stop  Center
>           (Mhz)  (Mhz) (Mhz) (Mhz)
>  1        3.2    20.0  23.2  21.6
>  2        3.2    23.2  26.4  24.8
>  3        1.6    20.0  21.6  20.8
>  4        1.6    21.6  23.2  22.4
>  5        1.6    23.2  24.8  24.0
>  6        1.6    24.8  26.4  25.6
>  7        1.6    26.4  28.0  27.4
```

Try to reduce the spectrum allocation when it is used with small channel widths. Otherwise, there will be a large number of upstream channel slots, and the frequency hopping may require several minutes to find a clean slot.

Other Spectrum Management Configuration Examples

To configure differing spectrum groups, refer to the following examples:

- Use the following example to add time-scheduled spectrum. You can add spectrum on a weekly schedule by including an optional weekday and time:

  ```
  Router(config)# cable spectrum-group 1 time Mon 08:00:00 frequency 21600000
  ```

  Use the **delete** keyword to delete the frequency:

  ```
  Router(config)# cable spectrum-group 1 time Mon 18:00:00 delete frequency 21600000
  ```

- Use the following example to configure spectrum group 1 with an upstream frequency of 6,500,000 Hz and a default power level of 0 dBmV:

  ```
  Router(config)# cable spectrum-group 1 frequency 6500000
  ```

- Use the following example to add the upstream frequency 7,000,000 Hz to the list of valid frequencies with a default power level of 0 dBmV for spectrum group 1:

  ```
  Router(config)# cable spectrum-group 1 frequency 7000000
  ```

- Use the following example to configure spectrum group 2 with an upstream frequency 7,500,000 Hz and change the power level to 5 dBmV:

  ```
  Router(config)# cable spectrum-group 2 frequency 7500000 5
  ```

- Use the following example to configure spectrum group 3 with an upstream band of 12,000,000 to 18,000,000 Hz and default power level of 0 dBmV:

  ```
  Router(config)# cable spectrum-group 3 band 12000000 18000000
  ```

- Use the following example to add the upstream band 20,000,000 to 24,000,000 Hz to the list of valid bands with a change in the power level of 13 dBmV for spectrum group 3:

  ```
  Router(config)# cable spectrum-group 3 band 20000000 24000000 13
  ```

- Use the following example to configure a continuous band between 5,000,004 and 40,000,000 Hz for scheduled spectrum group 4 with a default power level of 0 dBmV. The band is available to the spectrum group starting at 12:00 p.m. local time each Monday:

  ```
  Router(config)# cable spectrum-group 4 time Monday 12:00:00 band 5000004 40000000
  ```

- Use the following example to add the upstream frequency 9,500,000 Hz to the list of valid frequencies and change the nominal power level to 5 dBmV. The spectrum manager adjusts frequencies and power levels on this group at 2:00 a.m. local time each day:

  ```
  Router(config)# cable spectrum-group 3 time 02:00:00 frequency 9500000 5
  ```

- Use the following example to configure the minimum period before which a frequency hop can occur in seconds:

  ```
  Router(config)# cable spectrum-group 3 hop period 800
  ```

- Use the following example to configure the threshold value (expressed as a percentage) of the number of "offline" modems identified before the router initiates an automatic frequency hop:

  ```
  Router(config)# cable spectrum-group 3 hop threshold 40
  ```

- Use the following example to configure a particular spectrum group as a shared RF spectrum group. Specifying a given spectrum group as "shared" tells the router that you want to be sure that upstream frequencies assigned to upstream ports are not assigned to additional upstream ports:

  ```
  Router(config)# cable spectrum-group 3 shared
  ```

- Use the following example to remove a specified spectrum group from your configuration:

  ```
  Router(config)# no cable spectrum-group 3
  ```

- The following is an example of a spectrum group configuration that is designed to perform minor equalization as a function of frequency.

  ```
  CMTS01(config)# cable spectrum-group 1 frequency 21600000
  CMTS01(config)# cable spectrum-group 1 frequency 24800000 1
  CMTS01(config)# cable spectrum-group 1 frequency 28000000 2
  ```

  In this example, the upstream port receives power at 21.6 MHz with a default power level of 0 dBmV, at 24.8 MHz with a power level of 1 dBmV, and at 28.0 MHz with a power level of 2 dBmV. At any time, the power level set in the interface configuration overrides the spectrum group power level.

Dynamic Upstream Modulation Examples

The following examples describe how to display modulation profile information with the **show cable modulation-profile** command and to define a modulation profile with the **cable modulation-profile** command.

Verifying Your Settings

Step 1 To check the value of the settings you have entered, enter the **show running-config** command in privileged EXEC mode at the `Router#` prompt:

```
Router# show running-config
```

To review changes you make to the configuration, use the **show startup-config** command in privileged EXEC mode to display the information stored in NVRAM.

Step 2 To display modulation profile group information, use the **show cable modulation-profile** command in privileged EXEC mode:

```
Router# show cable modulation-profile [profile] [iuc-code]
```

profile—(Optional) Profile number. Valid values are from 1 to 8.

iuc-code—(Optional) Internal usage code.

Valid options are:

- **initial**—Initial ranging burst
- **long**—Long grant burst
- **request**—Request burst
- **short**—Short grant burst
- **station**—Station ranging burst

Modulation Profiles Example

In Cisco IOS Release 12.1(3a)EC1 and later, the Cisco CMTS has one preconfigured modulation profile resident in memory, which defines a typical profile for QPSK modulation. To use the Dynamic Upstream Modulation feature, a second profile must be created that is unique from the first profile, and typically provides a higher, more robust modulation scheme.

The following example is a modulation profile for QAM-16, in which the initial, request, and station maintenance messages are sent as QPSK, and the short and long data packets are sent as QAM-16. The QAM-16 modulation is more bandwidth-efficient than QPSK, but QPSK is more robust than QAM-16.

Note The upstream request and station maintenance messages use less time on the cable network when configured in QPSK for symbol rates of 640, 1280, and 2560K symbols/sec. Thus, these messages are actually more efficient when used in QPSK mode and they ensure a more reliable modem connection. The upstream initial maintenance message takes exactly the same amount of time on the cable network, no matter how it is configured. Modems connect more quickly and experience fewer cycles of power adjustment during initial maintenance if the system is set for QPSK.

```
Router# configure terminal
Router(config)# cable modulation-profile 2 request 0 16 1 8 qpsk scrambler
152 no-diff 64 fixed uw16
Router(config)# cable modulation-profile 2 initial 5 34 0 48 qpsk scrambler
152 no-diff 128 fixed uw16
Router(config)# cable modulation-profile 2 station 5 34 0 48 qpsk scrambler
152 no-diff 128 fixed uw16
Router(config)# cable modulation-profile 2 short 6 75 6 8 16qam scrambler 152
no-diff 72 fixed uw16
Router(config)# cable modulation-profile 2 long 8 220 0 8 16qam scrambler 152
no-diff 160 fixed uw16
```

In the following example, all message types are carried with QAM-16 modulation. Although QAM-16 modulation offers a consistent modulation scheme for all five types of messages, the added length of the QAM-16 preamble offsets the increased bandwidth efficiency of the MAC data message for the station maintenance messages and bandwidth request messages.

```
Router# configure terminal
Router(config)# cable modulation-profile 2 request 0 16 1 8 16qam scrambler
152 no-diff 128 fixed uw16
```

```
Router(config)# cable modulation-profile 2 initial 5 34 0 48 16qam
scrambler 152 no-diff 256 fixed uw16
Router(config)# cable modulation-profile 2 station 5 34 0 48 16qam
scrambler 152 no-diff 256 fixed uw16
Router(config)# cable modulation-profile 2 short 5 75 6 8 16qam scrambler
152 no-diff 144 fixed uw16
Router(config)# cable modulation-profile 2 long 8 220 0 8 16qam scrambler
152 no-diff 160 fixed uw16
```

Note When using DOCSIS concatenation with a 16-QAM or mixed symbol rate, configure the CMTS for Unique Word 16 ("uw16") in the preamble for both short and long data burst profiles.

Add the **cable upstream** *port-number* **modulation-profile** *primary profile-number secondary profile-number* command to the appropriate interfaces. In this example, modulation-profile 2 is for QAM-16 modulation and profile 1 is for QPSK modulation.

```
Router# configure terminal
Router(config)# interface Cable6/0
Router(config-if)# cable upstream 0 modulation-profile 2 1
```

Input Power Level Examples

In the following example, the modem transmit power at 24.8 MHz is adjusted upstream by 1 dBmV and the modem transmit power at 28.0 MHz is adjusted upstream by 2 dBmV.

```
CMTS01(config)# cable spectrum-group 1 frequency 21600000
CMTS01(config)# cable spectrum-group 1 frequency 24800000 1
CMTS01(config)# cable spectrum-group 1 frequency 28000000 2
```

Advanced Spectrum Management Configuration Examples

This section provides the following typical configurations:

- Advanced Spectrum Management for the Cisco uBR7200 Series Router, page 3-66
- Advanced Spectrum Management for the Cisco uBR10012 Router, page 3-69

Advanced Spectrum Management for the Cisco uBR7200 Series Router

This section provides a typical configuration example for a Cisco uBR7200 series router using the Cisco uBR-MC16S cable interface line card. This configuration does the following:

- Creates three spectrum groups with different frequency bands, hop periods, and hop thresholds.
- Creates two upstream modulation profiles, one for QPSK operation and one for QAM-16 operation, by specifying the parameters for each burst type.
- Creates two upstream modulation profiles, one for QPSK operation and one for mixed QPSK/QAM-16 operation, using the default profile options (**qpsk** and **mix**).
- Configures one upstream (port 5) on cable interface 3/0 to use spectrum group 3.
- Configures the upstreams with the primary modulation profile set to mixed QPSK/QAM-16 operation and the secondary modulation profile set for QPSK operation.

- Configures the upstream so that when its noise threshold is reached, it first attempts to change the frequency, then the channel-width, and finally to switch the modulation profile (using the Dynamic Upstream Modulation feature).

```
!
version 12.1
no service pad
no service password-encryption
service udp-small-servers
service tcp-small-servers
!
hostname ubr7200
!
!
! Define a frequency band for a 1.6 MHz channel around center frequency of 20.800 MHz
cable spectrum-group 1 band 19750000 21850000 0
! Define a frequency band for a 1.6 MHz channel around center frequency of 23.200 MHz
cable spectrum-group 1 band 22150000 24250000 0
! Hop period set to 30 sec to avoid modems going offline before initiating a hop priority
cable spectrum-group 1 hop period 30
! Percentage of missed station maintenance from modems
cable spectrum-group 1 hop threshold 20
!
cable modulation-profile 1 initial 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed uw16
cable modulation-profile 1 station 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed uw16

! Create second modulation profile numbered 4
cable modulation-profile 4 request 0 16 0 8 qpsk scrambler 152 no-diff 64 fixed uw16
cable modulation-profile 4 initial 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed uw16
cable modulation-profile 4 station 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed uw16
cable modulation-profile 4 short 6 75 6 8 16qam scrambler 152 no-diff 144 shortened uw16
cable modulation-profile 4 long 8 220 0 8 16qam scrambler 152 no-diff 160 shortened uw16

! Create two modulation profiles using the default QPSK and QPSK/16-QAM profiles
cable modulation-profile 3 qpsk
cable modulation-profile 5 mix
!
no cable qos permission create
no cable qos permission update
cable qos permission modems
cable time-server
clock calendar-valid
no ip subnet-zero
no ip domain-lookup
!
!
!
interface FastEthernet0/0
 no ip address
 no ip mroute-cache
 shutdown
 media-type MII
 full-duplex
!
interface Ethernet1/0
 ip address 10.11.10.1 255.0.0.0
 no ip mroute-cache
 half-duplex
!

interface Cable3/0
 ip address  255.255.255.0 secondary
 ip address  255.255.255.0
 no keepalive
 cable map-advance static
 cable bundle 1 master
 cable downstream annex B
```

```
 cable downstream modulation 64qam
 cable downstream interleave-depth 32
 cable downstream frequency 687000000
! Assign upstream to spectrum group
 cable upstream 0 spectrum-group 1
! Set channel-width to be fixed at 1.6 MHz
 cable upstream 0 channel-width 1600000 1600000
! Set priority of corrective actions
 cable upstream 0 hop-priority frequency channel-width modulation
! Set the thresholds for corrective action
 cable upstream 0 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
! Assign modulation profiles to upstream port in order of preference
 cable upstream 0 modulation-profile 5 1
 no cable upstream 0 concatenation
 no cable upstream 0 shutdown
 cable upstream 1 spectrum-group 1
 cable upstream 1 channel-width 1600000 1600000
 cable upstream 1 hop-priority frequency channel-width modulation
 cable upstream 1 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 1 modulation-profile 5 1
 no cable upstream 1 concatenation
 no cable upstream 1 shutdown
 cable upstream 2 spectrum-group 1
 cable upstream 2 channel-width 1600000 1600000
 cable upstream 2 hop-priority frequency channel-width modulation
 cable upstream 2 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 2 modulation-profile 5 1
 no cable upstream 2 concatenation
 no cable upstream 2 shutdown
 cable upstream 3 spectrum-group 1
 cable upstream 3 channel-width 1600000 1600000
 cable upstream 3 hop-priority frequency channel-width modulation
 cable upstream 3 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 3 modulation-profile 5 1
 no cable upstream 3 concatenation
 no cable upstream 3 shutdown
 cable upstream 4 spectrum-group 1
 cable upstream 4 channel-width 1600000 1600000
 cable upstream 4 hop-priority frequency channel-width modulation
 cable upstream 4 threshold cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 4 modulation-profile 5 1
 no cable upstream 4 concatenation
 no cable upstream 4 shutdown
 cable upstream 5 spectrum-group 1
 cable upstream 5 channel-width 1600000 1600000
 cable upstream 5 hop-priority frequency channel-width modulation
 cable upstream 5 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 5 modulation-profile 5 1
 no cable upstream 5 concatenation
 no cable upstream 5 shutdown
 no cable dci-response
 cable dhcp-giaddr policy
!
interface Cable4/0
 no ip address
 no keepalive
 cable map-advance static
 cable bundle 1
 cable downstream annex B
 cable downstream modulation 64qam
 cable downstream interleave-depth 32
 cable downstream frequency 687000000
 cable upstream 0 spectrum-group 1
 cable upstream 0 channel-width 1600000 1600000
 cable upstream 0 hop-priority frequency channel-width modulation
 cable upstream 0 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 0 modulation-profile 5 1
 no cable upstream 0 concatenation
 no cable upstream 0 shutdown
 cable upstream 1 spectrum-group 1
 cable upstream 1 channel-width 1600000 1600000
```

```
 cable upstream 1 hop-priority frequency channel-width modulation
 cable upstream 1 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 1 modulation-profile 5 1
 no cable upstream 1 concatenation
 no cable upstream 1 shutdown
 cable upstream 2 spectrum-group 1
 cable upstream 2 channel-width 1600000 1600000
 cable upstream 2 hop-priority frequency channel-width modulation
 cable upstream 2 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 2 modulation-profile 5 1
 no cable upstream 2 concatenation
 no cable upstream 2 shutdown
 cable upstream 3 spectrum-group 1
 cable upstream 3 channel-width 1600000 1600000
 cable upstream 3 hop-priority frequency channel-width modulation
 cable upstream 3 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 3 modulation-profile 5 1
 no cable upstream 3 concatenation
 no cable upstream 3 shutdown
 cable upstream 4 spectrum-group 1
 cable upstream 4 channel-width 1600000 1600000
 cable upstream 4 hop-priority frequency channel-width modulation
 cable upstream 4 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 4 modulation-profile 5 1
 no cable upstream 4 concatenation
 no cable upstream 4 shutdown
 cable upstream 5 spectrum-group 1
 cable upstream 5 channel-width 1600000 1600000
 cable upstream 5 hop-priority frequency channel-width modulation
 cable upstream 5 threshold  cnr-profile1 23 cnr-profile2 15 Corr-Fec 5 Uncorr-Fec 1
 cable upstream 5 modulation-profile 5 1
 no cable upstream 5 concatenation
 no cable upstream 5 shutdown
 no cable dci-response
 cable dhcp-giaddr primary
!
ip default-gateway 10.11.0.1
ip classless
ip route 10.11.254.254 255.255.255.255 10.11.0.1
no ip http server
!
!
snmp-server engineID local 00000009020000D0CAA7BB00
snmp-server community private RW
snmp-server trap-source FastEthernet0/0
snmp-server packetsize 2048
snmp-server system-shutdown
snmp-server enable traps cable hopping
snmp-server manager
!
!
line con 0
 exec-timeout 0 0
 transport input none
line aux 0
line vty 0 4
 no login
!
end
```

Advanced Spectrum Management for the Cisco uBR10012 Router

This section provides an excerpt from a typical configuration example for a Cisco uBR10012 router using the Cisco uBR-LCP2-MC16S cable interface line card. This configuration does the following:

- Configures four spectrum groups with a hop period of 30 seconds.
- Creates a QPSK modulation profile and assigns it to four upstreams on the Cisco uBR-LCP2-MC16S cable interface line card in slot 6/1/0.

- Assigns a spectrum group to each of the four upstreams.
- Configures each upstream for the default CNR and FEC thresholds.

```
Current configuration : 4899 bytes
!
version 12.2
no service pad
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
service internal
!
hostname UBR10012
!
no logging rate-limit
!
redundancy
  main-cpu
   auto-sync standard
card 1/0 1gigethernet-1
card 1/1 2cable-tccplus
card 4/0 1oc12pos-1
card 6/1 1cable-mc16s
card 7/0 1cable-mc16s
card 8/0 1cable-mc16s
card 8/1 1cable-mc16s
cable spectrum-group 1 hop period 30
cable spectrum-group 1 band 6000000 11000000
cable spectrum-group 2 hop period 30
cable spectrum-group 2 band 12000000 17000000
cable spectrum-group 3 hop period 30
cable spectrum-group 3 band 18000000 23000000
cable spectrum-group 4 hop period 30
cable spectrum-group 4 band 24000000 31000000
cable modulation-profile 2 qpsk
interface Cable6/1/0
  ip address 10.55.0.1 255.255.0.0
  cable downstream annex B
  cable downstream modulation 64qam
  cable downstream interleave-depth 32
! upstream 0
  cable upstream 0 spectrum-group 1
  cable upstream 0 modulation-profile 2
  cable upstream 0 threshold  cnr-profile1 16 cnr-profile2 5 Corr-Fec 1 Uncorr-Fec 1
  no cable upstream 0 shutdown
! upstream 1
  cable upstream 1 spectrum-group 2
  cable upstream 1 modulation-profile 2
  cable upstream 1 threshold  cnr-profile1 16 cnr-profile2 5 Corr-Fec 1 Uncorr-Fec 1
  no cable upstream 1 shutdown
! upstream 2
  cable upstream 2 spectrum-group 3
  cable upstream 2 modulation-profile 2
  cable upstream 2 threshold  cnr-profile1 16 cnr-profile2 5 Corr-Fec 1 Uncorr-Fec 1
  no cable upstream 2 shutdown
! upstream 3
  cable upstream 3 spectrum-group 4
  cable upstream 3 modulation-profile 2
  cable upstream 3 threshold  cnr-profile1 16 cnr-profile2 5 Corr-Fec 1 Uncorr-Fec 1
  no cable upstream 3 shutdown
```